Probabilistic seismic hazard analysis of events occurred in Albania

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ABSTRACT

Albania is a seismic region so the goal of many earthquake engineers is to ensure the durability of a structure for a given level of ground vibration. There are many uncertainties about magnitude, location and the intensity of the future earthquake. Probability methods allow us to speak quantitatively about variables phenomenon. Probabilistic Seismic Hazard Analysis (PSHA) aims to reveal these uncertain and to produce the distribution of the future earthquakes that may occur. The purpose of this paper is to discuss the calculation involved in PSHA and to give some qualifications about the probability of intense ground vibration at a place and their associated rates of exceedance. The results can be used to identify the ground vibration intensity, which has small probability of being exceeded. In calculation are involved the location and intensity of all the seismic events occurred in Albania.

Keywords: *earthquake, PSHA, rates of exceedance, PGA*

1. INTRODUCTION

Albania is a seismic region so the goal of earthquake engineering analyses is to ensure the structures for a given ground shaking while maintaining a good performance. The earthquakes are stochastic phenomena so one of the best methods of prediction is a probabilistic method. We know that the seismic events have some uncertainties about the future events expected. These uncertainties include size, location, intensity etc, so the Probabilistic Seismic Hazard Analyses (PSHA) aims to combine these and make a future prediction for the upcoming events. The Probabilistic Seismic Hazard Analysis is a method used in the Eurocode EC8.

The acceleration (PGA) refers to the value of seismic acceleration in a hard rock, who for P=90% will be not exceeded for t=50 years or the acceleration caused by an earthquake with RP=475 years (designing earthquake)

The dates of this calculation are used from local or national administrators to minimize the risk, geologist engineers, seismographs, architects and project engineers.

The first thing to do is to determine the annual probability of exceeding some levels of earthquake ground shaking at a site and then to evaluate the risk of a structure.

The purpose of this paper is to discuss the calculation involved in PSHA because probability calculations are a critical part of the procedures described here.

With PSHA we are no looking for worst-case ground motion intensity, but we consider all possible earthquake events that have occurred in Albania along with their associated probabilities of occurrence ,in order to find the level of ground motion intensity exceeded .

2. EARTHQUAKE SOURCES

This method is interested in the identification of all the earthquake sources capable of producing ground motions at a site. These sources could be faults, which are planar surfaces identified through observations of past earthquake locations and geological evidence. There are also individual sources of earthquake and if they are not identifiable these sources could be explained as area sources. In Albanian region are active ten seismic source zones described in Table 1.

Table.1 Parameters for the ten seismic source zones

Zone name/Code	Zone area (km^2)	Earthquakes used	β	A (No)	Mx	Rate of M>6 p.a	Rate density
Ohrid-Korca, KO	2760	44	1.44	242	6.9	0.0315	11.4
Kukesi-Peshkopia, KP	1480	21	1.75	481	6.9	0.0104	7.0
Ionian Coast, IC	16600	151	1.40	692	7.0	0.115	6.9
Elbasani-Dibra-Tetova, EDT	2660	46	1.99	3142	6.9	0.0167	6.3
Periadriatic Lowland, PL	7460	75	1.61	914	7.0	0.0458	6.1
Lezha-Ulqini, LU	5140	39	1.52	293	7.2	0.0272	5.3
Skopje, SK	3300	5	2.08	2541	7.2	0.00913	2.8
Shkodra-Tropoja, ST	1570	11	1.99	778	6.9	0.00418	2.7
Peja-Prizreni, PP	1740	5	2.03F	418	6.8	0.00173	1.0
EasternAlbanian Backgr, EAB	57200	75	2.03F	6075	6.5	0.0199	0.35

3. PROBABILISTIC HAZARD ANALYSIS

PSHA is first developed by Cornell (1968) and his methods were adopted for evaluating hazard. The hazard curves obtained from PSHA show the variation of Peak Ground Acceleration against means of annual rate of exceedance. The occurrence of an earthquake is assumed to follow Poisson’s distribution. The estimation of seismic hazard values in any region needs the complete details of past earthquakes. In this calculations I have obtained 134 seismic events occurred in Albania from 1905-2014 capable producing damages (considering all earthquakes with magnitude greater than 5).These data include the depth, magnitude, time etc. The earthquake data are collected from IGJEUM (Institute of Geosciences, Energy, Water and Environment)

3.1 IDENTIFICATION OF MAGNITUDES

Seismic faults are capable producing different scales of earthquakes. Gutenberg and Ritcher observed the earthquakes magnitudes and they saw that the distribution of earthquake sizes at a site usually follow the law (1):

$$\log\lambda_m = a - bm \quad (1)$$

where, λ_m is the rate of earthquakes with M>m and a, b are constants.
This equation is called Gutenberg-Ritcher recurrence law. For magnitudes from 3-8, and a=b=1, in figure (1) is showed a typical distribution of observed magnitudes, along with Gutenberg-Ritcher law.

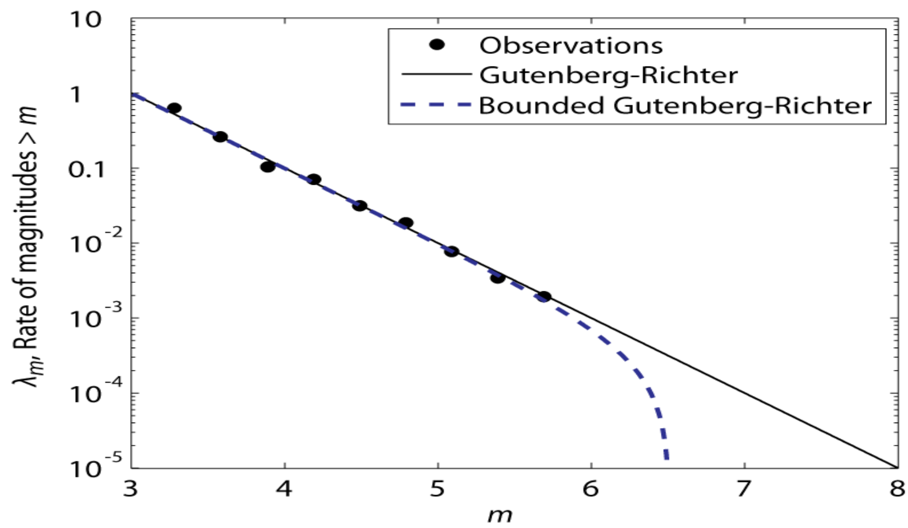

Figure.1 Typical distribution of observed magnitudes

Equation (1) can be used to calculate a Cumulative Density Function CDF for magnitudes greater than minimum m and smaller than maximum M.

$$F_M(m) = \frac{1-10^{-b(m-m_{min})}}{1-10^{-b(m_{max}-m_{min})}}, \quad m_{min} < m < m_{max} \quad (2)$$

While deriving equation (2) we obtain a Probability Density Function PDF

$$f_M(m) = \frac{b\ln(10)10^{-b(m-m_{min})}}{1-10^{-b(m_{max}-m_{min})}}, \quad m_{min} < m < m_{max} \quad (3)$$

where, M_{max} is the maximum magnitude that a source can produce. This limited distribution of magnitude is known as Gutenberg – Ritcher law. For further equation of PSHA we will convert the continued distribution of magnitudes in a discrete set of magnitudes. The discrete values can be found through formula (4):

$$P(M = m_j) = F_M(m_{j+1}) - F_M(m_j) \quad (4)$$

where m_j, are the discrete values of magnitudes sorted in a certain way that $m_j < m_{j+1.}$
At the Table.2 is showed the CDF for the magnitudes and the PDF as well.

Table.2 CDF and PDF for the magnitudes of the earthquakes

MAGNITUDE	F_M (mj)	P (M=mj)
5	0.000	0.206
5.1	0.206	0.164
5.2	0.369	0.13
5.3	0.499	0.103
5.4	0.602	0.082
5.5	0.684	0.065
5.6	0.750	0.052
5.7	0.801	0.041
5.8	0.842	0.033
5.9	0.875	0.026
6	0.901	0.021
6.1	0.921	0.016
6.4	0.961	0.01
6.6	0.976	0.007
6.7	0.981	0.005
6.8	0.985	0.003
6.9	0.988	0.003
7	0.991	0.002

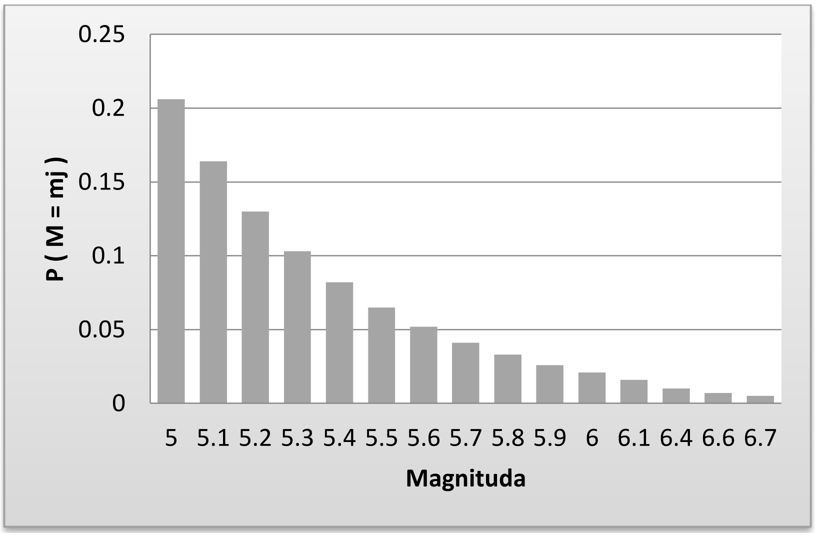

Figure.2 The discrete probability values of PDF from formula (4)

4. EARTHQUAKE DISTANCES

The distribution of the distances from earthquake to the site of interest is important to predict the ground shaking at a site. We assume that for a given earthquake source the probability to occur in any location is equal. According to this, is simple to identify the distribution of source to site distances using the geometry of the sources.
This model is appropriate for modeling faults that exist on the boundary of two tectonic plates.

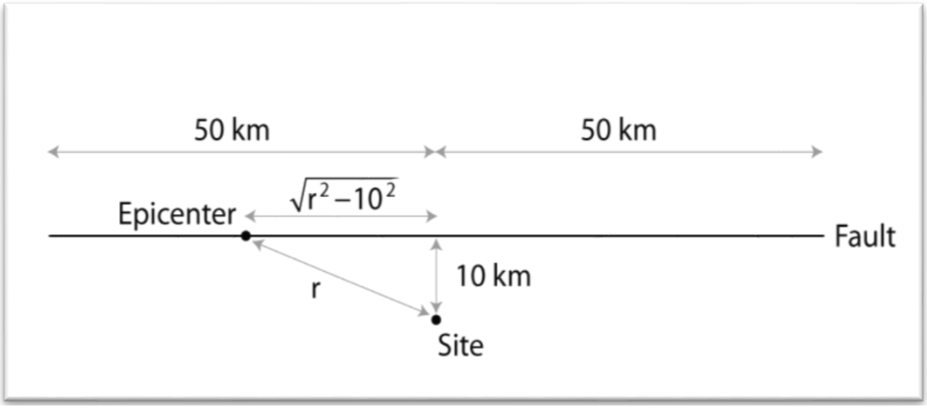

Figure 3. Ilustration of the model of line source

Considering a 100 km fault, with a site located 10 km from the center and in this case the propability to observe a distance of less than r is equal to the fraction of the fault located with a radius of r. So, we can compute the CDF of R

$$F_R(r) = P(R \leq r) = \frac{\text{gjatesia e carjes me distance r}}{\text{gjatesia totale e carjes}} = \frac{2\sqrt{r^2-10^2}}{100} \quad (5)$$

The equation is true for distances less than 10 km and greater than 51 km. Distances out of this range are impossible, so the CDF is:

$$F_R(r) = \begin{cases} 0 & \text{nese } r < 10 \\ \frac{2\sqrt{r^2-10^2}}{100} & \text{nese } 10 \leq r < 51 \\ 1 & \text{nese } r \geq 51 \end{cases} \quad (6)$$

The PDF and CDF are plotted in the figure (4).

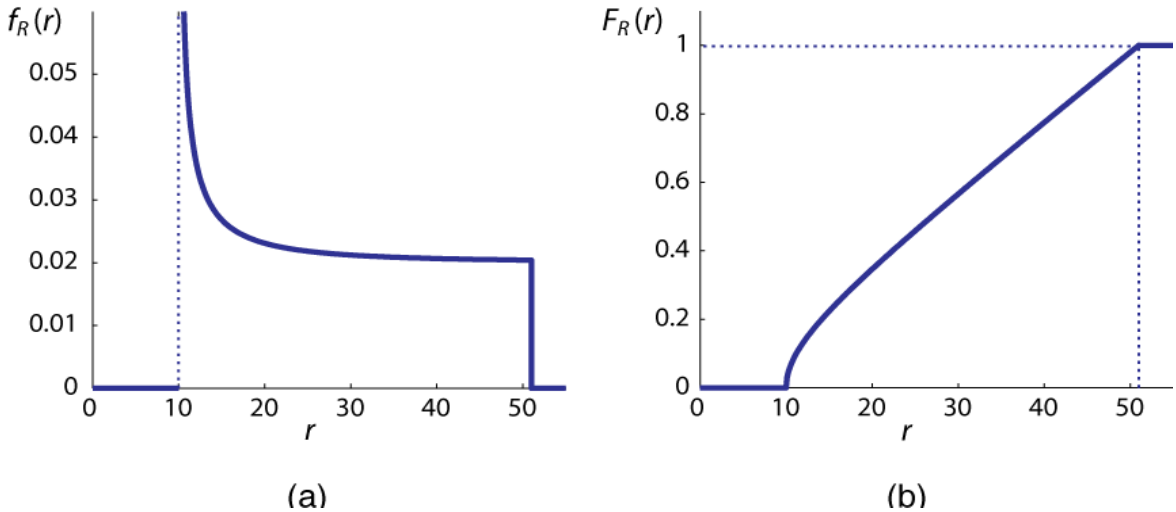

Figure.4. The CDF (a) and PDF (b) of the distance source to site for the future earthquakes

5. GROUND MOTION INTENSITY

The next step is a ground motion prediction model and these models are called attenuation relations. The chosen model predicts the probability of ground motion intensity, as a function of many variables such as: magnitude, distance, faulting mechanism, the near surface site conditions and the potential presence of other effects. To describe the probability distribution, the prediction models are in this form:

$$\ln IM = \overline{\ln IM(M,R,\theta) + \sigma(M,R,\theta) * \varepsilon} \quad (7)$$

where, ln*IM* is the natural log of ground motion intensity measure (such as spectral acceleration at a given period). The terms ln*IM*(M,R,θ) and σ(M,R, θ), are the output of the ground motion prediction model, the predicted and the standard deviation respectively of ln*IM*. There are many methods for the mean of PGA, but we choose to use the prediction model for horizontal response spectra in Europe by Ambrasey, Simpson and Bommer (1996).[2]. They predicted the following model for the mean of peak ground acceleration:

$$\ln PGA = -1.09 + 0.238\ m - 0.0005r - \log(r) \quad (8)$$

where, h_o=6km,σlogε=0.28.The mean depth of the earthquakes in Albania is 10 km, but in Ambrasey relations this parameter is not used ,so this will not be part of hazard calculation.

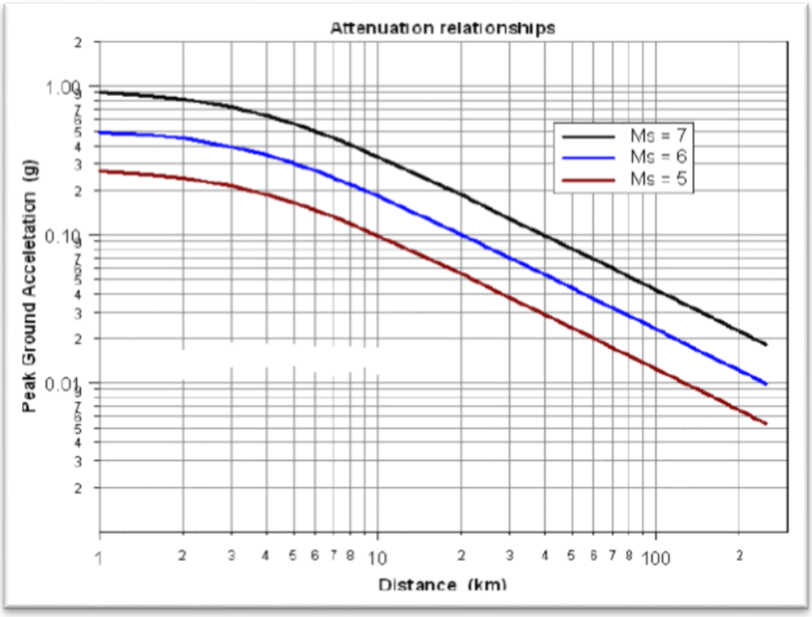

Figure.5 PGA attenuation relationships for European region by Ambrasey, Simpson and Bommer

Table.3 The calculation of a_g with Ambrasey, Simpson and Bommer formulas

(a *)	log(a *)	h_0 (km)	d (km)	m	r (km)	logr	log(D)	ag/g
0.2055217	-0.6871422	6	1	5	6.0827625	0.7841009	0.000	0.0209502
0.0127587	-1.8941923	6	2	5	6.3245553	0.80103	0.301	0.0013006
0.1862257	-0.7299604	6	3	5	6.7082039	0.8266063	0.477	0.0189833
0.1731382	-0.7616072	6	4	5	7.2111026	0.8580017	0.602	0.0176491
0.159746	-0.79657	6	5	5	7.8102497	0.8926649	0.699	0.016284
0.1469234	-0.8329089	6	6	5	8.4852814	0.9286662	0.778	0.0149769
0.1351079	-0.8693192	6	7	5	9.2195445	0.9647095	0.845	0.0137725
0.1244515	-0.905	6	8	5	10	1	0.903	0.0126862
0.1149473	-0.9395013	6	9	5	10.816654	1.0340929	0.954	0.0117174
0.0764895	-1.116398	6	5	5	16.155494	1.2083203	1.176	0.0077971
0.0588595	-1.2301836	6	20	5	20.880613	1.3197432	1.301	0.0059999
0.0397251	-1.400935	6	30	5	30.594117	1.4856379	1.477	0.0040494
0.0297088	-1.5271154	6	40	5	40.447497	1.6068916	1.602	0.0030284
0.023591	-1.627254	6	50	5	50.358713	1.7020746	1.699	0.0024048
0.0194777	-1.7104616	6	60	5	60.299254	1.7803119	1.778	0.0019855
0.0165266	-1.7818159	6	70	5	70.256672	1.8466876	1.845	0.0016847
0.014308	-1.8444204	6	80	5	80.224684	1.904308	1.903	0.0014585
0.0125804	-1.9003054	6	90	5	90.199778	1.9552055	1.954	0.0012824
0.0111977	-1.9508702	6	100	5	100.17984	2.0007803	2.000	0.0011415

It is proved that the values are distributed in a significative way just like the prediction. The ε coefficient extracted from the PGA values grows up in a lognormal law, so ln(ε) follows a normal law. The PDF of lognormal variable can be written as:

$$f_2(a_g) = \frac{1}{a_g \sigma_{\ln\varepsilon}\sqrt{2\pi}} \exp\left\{-\frac{1}{2}\left[\frac{1}{\sigma_{\ln\varepsilon}} \ln\left(\frac{a_g^2}{a_g^*}\right)\right]\right. \quad (9)$$

Table.4 The PDF of the lognormal variables a_g

a_g	a_g*	σ	$f_2(a_g)$
0.0001	0.2	0.62	1.49E-29
0.05	0.2	0.62	1.056887
0.1	0.2	0.62	3.445252
0.15	0.2	0.62	3.852881
0.2	0.2	0.62	3.218092
0.25	0.2	0.62	2.413017
0.3	0.2	0.62	1.732354
0.35	0.2	0.62	1.223633
0.4	0.2	0.62	0.861313
0.45	0.2	0.62	0.608042
0.5	0.2	0.62	0.431892
0.55	0.2	0.62	0.30916
0.6	0.2	0.62	0.223189
0.65	0.2	0.62	0.162533
0.7	0.2	0.62	0.11939
0.75	0.2	0.62	0.088444
0.8	0.2	0.62	0.066055
0.85	0.2	0.62	0.049722
0.9	0.2	0.62	0.037709
0.95	0.2	0.62	0.028803
1	0.2	0.62	0.02215

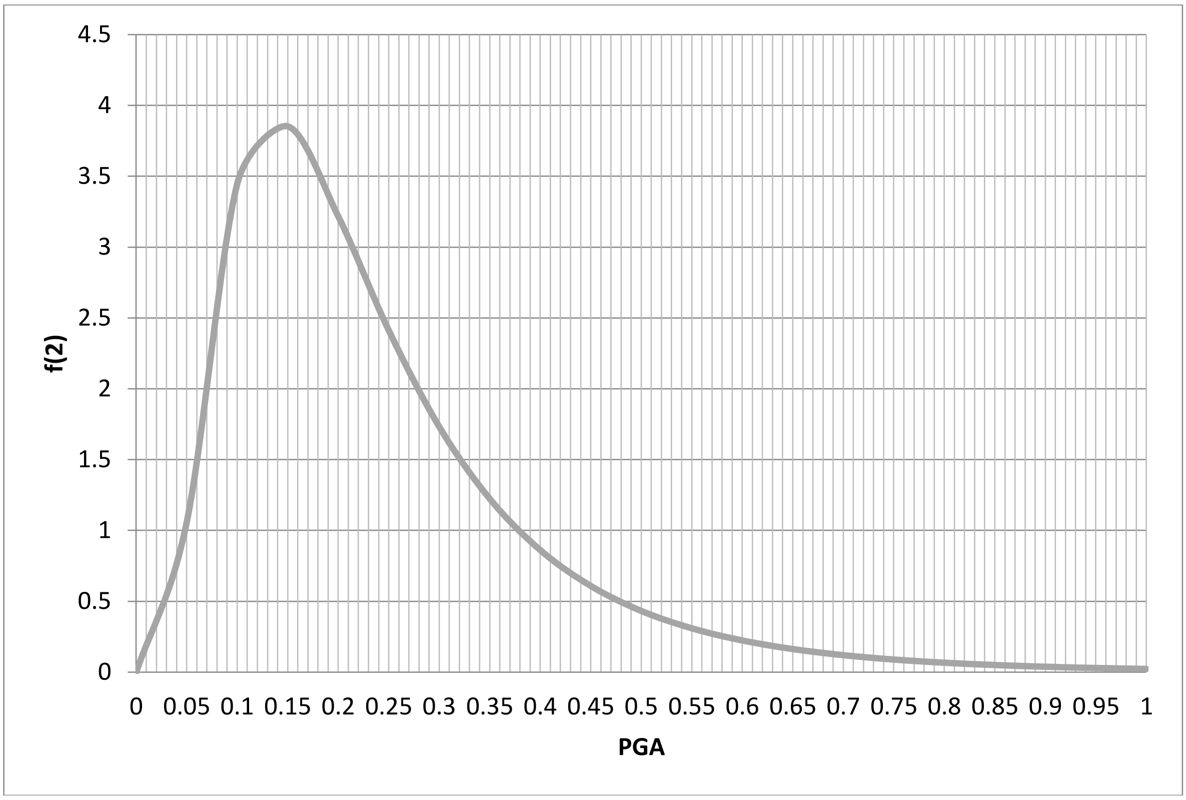

Figure.6 The graphic of lognormal distribution of PGA

6. THE PROPABILITY OF EXCEEDANCE

The probability of exceedance is calculated for three representative earthquakes and the results are calculated with the formula (10) for a period of 1 year and 50 years.

$$P_{TL}(A_g > a_g) = 1 - e^{-w_{TL}} \quad (10)$$

Table .5 Calculating the propability of exceedance

	M=5	M=5	M=5	$w_i=\alpha*P$			
	D=4Km	D=7Km	D=15Km				
	a_g*	a_g*	a_g*				
a_g	0.2	0.115	0.058	w_1	w_2	w_3	$w=\Sigma w_i$
0.0001	100	100	100	0.210526316	0.210526316	0.210526316	0.631578947
0.05	97.63083114	91.40146	66.44546	0.205538592	0.192424131	0.139885178	0.537847901
0.1	83.0269472	64.11685	18.3465	0.174793573	0.134982852	0.038624206	0.348400631
0.15	57.70567171	33.40739	0.240942	0.121485625	0.070331339	0.000507247	0.192324211
0.2	35.39390019	15.44694	0	0.074513474	0.032519875	0	0.107033349
0.25	20.58017045	6.809861	0	0.043326675	0.014336549	0	0.057663223
0.3	11.78003028	2.852054	0	0.024800064	0.006004324	0	0.030804388
0.35	6.766921278	1.035205	0	0.01424615	0.002179379	0	0.016425529

0.4	3.943388866	0.184193	0	0.008301871	0.000387774	0	0.008689646
0.45	2.348241185	0	0	0.004943666	0	0	0.004943666
0.5	1.437984544	0	0	0.003027336	0	0	0.003027336
0.55	0.911571449	0	0	0.001919098	0	0	0.001919098
0.6	0.602604041	0	0	0.00126864	0	0	0.00126864
0.65	0.41848177	0	0	0.000881014	0	0	0.000881014
0.7	0.30708954	0	0	0.000646504	0	0	0.000646504
0.75	0.238701752	0	0	0.00050253	0	0	0.00050253
0.8	0.196119135	0	0	0.000412882	0	0	0.000412882
0.85	0.169244559	0	0	0.000356304	0	0	0.000356304
0.9	0.152064585	0	0	0.000320136	0	0	0.000320136
0.95	0.140947431	0	0	0.000296731	0	0	0.000296731
1	0.133669923	0	0	0.00028141	0	0	0.00028141

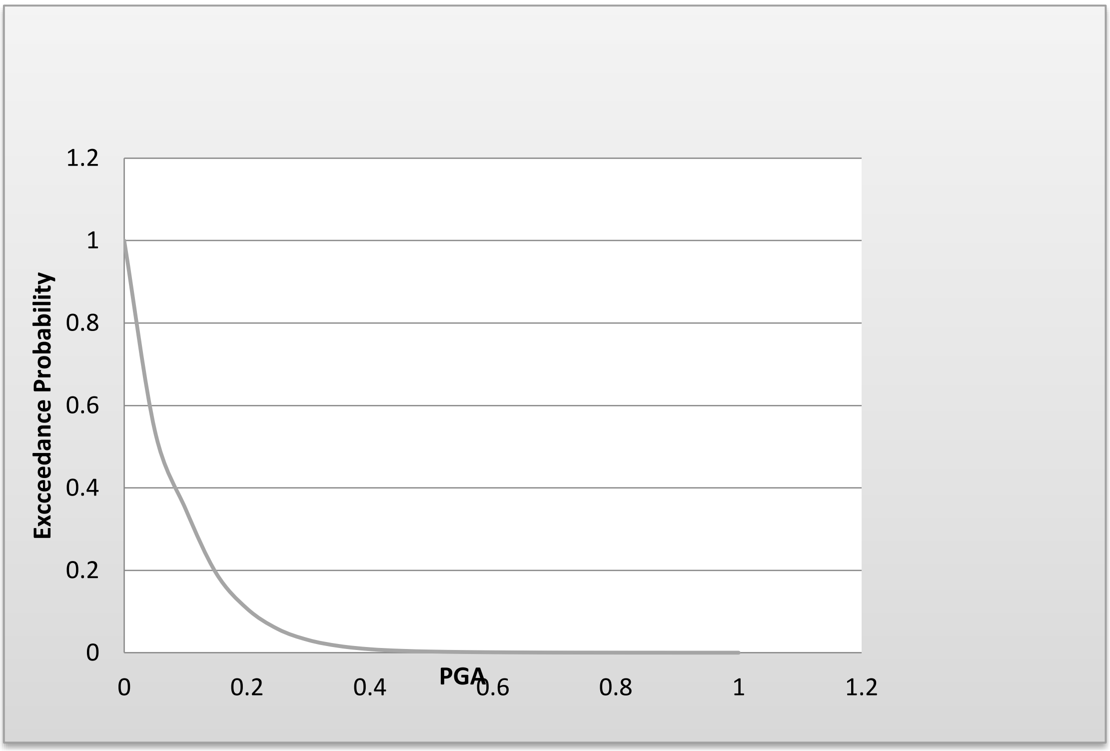

Figure.8 The hazard curve

Table.6 The probabilities of exceedance for three different earthquakes and their sumary

	M=5, D=3	**a_g*=0.2**	**w_1**
E(0.05)	0.02	0.95	**0.019**
E(0.1)	0.02	0.75	**0.015**
E(0.15)	0.02	0.5	**0.01**
E(0.2)	0.02	0.4	**0.008**
E(0.4)	0.02	0.075	**0.0015**
E(0.45)	0.02	0.05	**0.001**

	M=5, D=9	**a_g*=0.115**	**w_2**
E(0.05)	0.02	0.95	**0.019**
E(0.1)	0.02	0.85	**0.017**
E(0.15)	0.02	0.50	**0.01**
E(0.2)	0.02	0.25	**0.005**
E(0.4)	0.02	0.03	**0.0006**
E(0.45)	0.02	0.00	**0**

	M=5, D=50	**a_g*=0.06**	**w_3**
E(0.05)	0.02	0.95	**0.019**
E(0.1)	0.02	0.25	**0.005**
E(0.15)	0.02	0.15	**0.003**
E(0.2)	0.02	0.05	**0.001**
E(0.4)	0.02	0.00	**0**
E(0.45)	0.02	0.00	**0**

a_g	**$w=\Sigma w_i$**
E(0.05)	0.057
E(0.1)	0.037
E(0.15)	0.023
E(0.2)	0.014
E(0.4)	0.0021
E(0.45)	0.001

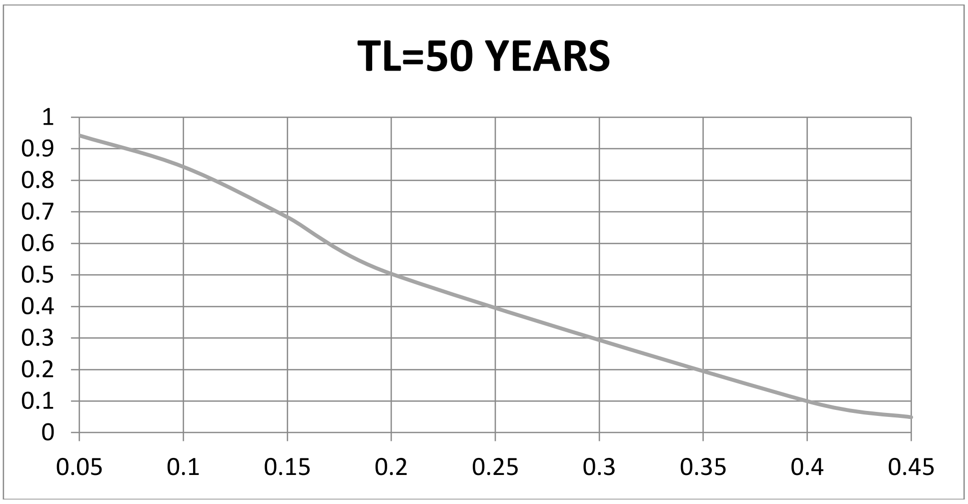

Figure .7 The graphic of propability of exceedance for T_L=50 years

T_L (Time Life)	w	0.057	0.037	0.023	0.014	0.0021	0.001
a_g		0.05	0.1	0.15	0.2	0.4	0.45
50	P	0.942156	0.842762834	0.683363	0.503415	0.099675477	0.048770575
1	P	0.055406	0.036323865	0.022738	0.013902	0.002097797	0.0009995

Table 7. The probability of exceedance for 1 and 50 years

CONCLUSIONS

The concepts and the methodology used in this paper is only a introduction to the propabilistic seismic hazard analysis and the importance at engineering.The work presented here is no way conclusive and intends to make a little introduction to the seismic hazard using PSHA.This method is easy interpreted and can be easily applied to seismic computions.

REFERENCES

[10] Baker 2008, Intro to the PSHA ,v1-3

[11] Ambraseys, N.N ,Simpson ,K.A ,Bommer , J.J .1996.Prediction of horizontal response spectra in Europe.*Earthquake Engineering and Structural Dynamics.*

[12] Baker,J.W., and Cornell,C.A (2006).”Correlation of response spectra values for multi-component ground motions”*Bulletin of the Seismological Society of America*

[13] Gutenberg ,B., and Richter, C.F (1944).”Frequency of earthquakes in California.”