STATISTICAL APPROACHES TO ESTIMATING THE RECURRENCE OF EARTHQUAKES IN THE EASTERN MEDITERRANEAN REGION

DOĞU AKDENİZ BÖLGESİ DEPREMLERİNİN TEKRARLANMA PERİYOTLARININ TAHMİNİNDE İSTATİSTİKSEL YAKLAŞIMLAR

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ABSTRACT: Risk analyses made in an area of seismic activity are going to be of great importance in determining earthquake occurence intervals and recurrence periods. Several methods, some of which include statistical methods, have been developed for this purpose. Gamma, Weibull distributions and Markov, Poisson, Gumbel are the most frequently used methods in this regard. In this study, instrumental records of 165 earthquakes of Ms ≥ 4 which occured in Eastern Mediterranean Region (Çukurova, Turkey) were investigated. These earthquake records were obtained from the Turkish Earthquake Research Department (ERD). To explain the seismic activity of the area, the relationship between magnitude and frequency was explained by using earthquake distribution in time. The magnitude-frequency relationship of the study area was calculated by means of the "Log N= 6.29 – 0.96 M" equation. Occurrence probability and recurrence periods of the earthquakes were computed by utilizing Poisson, Gumbell and Exponential Distribution Models and the results were correlated. The recurrence period of a 6.2 magnitude earthquake was determined as 63.23 years with the exponential distribution models. Poisson and Gumbel models, on the other hand, indicated, respectively, 102.56 and 101.40 years for the same magnitude. The exponential distribution model resulted in similar values with other models for an earthquake magnitude of ≥ 5.2 as regards the number of annual earthquake recurrence. It was found out that the exponential distribution model produced smaller values than other methods regarding the recurrence periods.

Key Words: Eastern Mediterranean, Çukurova region, Seismic risk, Earthquake return period, Exponential distribution function model, Poisson model, Gumbel model

ÖZ: Sismik aktivitesi olan bölgelerde yapılan risk analizleri depremlerin oluş sıklıklarının ve tekrarlanma periyotlarının belirlenmesi açısından önem kazanmaktadır. Bu amaçla çeşitli modeller oluşturulmuş olup, bunların bir kısmı istatistiksel yöntemleri içermektedir. Gamma ve Weibull dağılımları ile Markov, Poisson ve Gumbel bu amaçla en sık kullanılan modellerdir. Bu çalışmada Doğu Akdeniz (Çukurova) bölgesinde meydana gelmiş magnitüdleri 4 ve daha büyük olan 165 adet aletsel dönem deprem verisi incelenmiştir. Bölgenin deprem etkinliğini ortaya koymak için depremlerin zaman içindeki dağılımları ele alınarak magnitüd – frekans ilişkileri ortaya konmuştur. Bu çalışma ile incelenen bölgeye ait magnitüd- frekans ilişkisi Log N = 6.29 – 0.96 M bağıntısı ile ortaya konulmuştur. İstatistiksel hesaplamalar için üstel dağılım fonksiyonu, Poisson modeli ve Gumbel modeli kullanılarak depremlerin gelecekte olma olasılıkları ve tekrarlanma periyotları hesaplanmış ve incelenen üç model karşılaştırılmıştır. Üstel dağılım modeli ile 6.2 büyüklüğündeki bir depremin tekrarlanma periyodunu 63.23 yıl ve Poisson modeli ile 102.56 yıl olarak elde edilmiştir. Gumbel modeli ise aynı büyüklük değeri için 101.40 yıl olarak vermektedir. Üstel dağılım fonksiyonu modeli, yıllık deprem oluş sayıları bakımından ≥ 5.2 büyüklüklü depremler için diğer modellerle uyumlu değerler vermektedir. Tekrarlanma periyodu değerleri açısından ise üstel dağılım fonksiyonu modelinin diğer modellerden daha düşük değerler ortaya koydukları belirlenmiştir.

Anahtar Kelimeler: Doğu Akdeniz, Çukurova bölgesi, Sismik risk, Deprem tekrarlanma periyodu, Üstel dağılım fonksiyonu modeli, Poisson modeli, Gumbel modeli

INTRODUCTION

The seismic risk analysis based on the historical earthquake data, is one of the methods utilized in order to determine the seismicity of an area. Elastic rebound theory shows that earthquakes occurring on any fault or fault section are related to historical earthquakes. The number of recurrence as well as occurence time of possible earthquakes in the future can be identified using the seismic data, which were recorded during the earthquakes. For this purpose, different distribution models such as Poisson, Gumbell and Markov are commonly utilized.

Van Gelder (1997) investigated the records of earthquakes which occured in the last century and suggested a new statistical model in order to explain Gutenberg and Richter magnitude relations for the earthquakes resulting from the Vrancea fault in Romania.

Bağcı (2000) brought up a magnitude-frequency equation for the province of Izmir and its surroundings by investigating the 4.0 or larger magnitude earthquakes which took place in the area during 1900-1999. The researcher attempted to determine the recurrence probability of earthquakes in the future by utilizing Poisson and Gumbell distributions models.

In order to describe the seismicity of the Çukurova region, Ulutaş et al. (2001) brought up magnitude-frequency relations for the area of 35.5^o – 38^o N latitude and 34.5^o -37^o E longitude by means of “Log N=6.06 – 0.94 M” formula. Their seismic risk analysis made use use of the Poisson, Gumbell and Weibull models fort he study area and determined the recurrence periods accordingly.

Campbell et al. (2002) formed a seismic risk model for Taiwan, depending upon tectonic and seismic data. In their study, the relationship between M_L local magnitude scale and M_w moment magnitude scale used in Taiwan were investigated and some equations were proposed. Maximum earthquake magnitude was defined by investigating the historical earthquakes in the area and recurrence periods of earthquakes with a magnitude of 4.0-8.0 M_w moment magnitude were calculated. According to this study, the recurrence period of earthquakes with a magnitude of 6.5-7.0 was determined as 100 years for that area.

STUDY AREA AND RESEARCH METHOD

This paper analyzes the earthquakes of 4 or larger magnitude values which occurred in the area situated between 35.60^o - 38.50^o N and 33.50^o - 36.91^o E coordinates (East Mediterranean, Turkey) between the years of 1900 and 2001 (Figure 1). The study area is located in the Çukurova region of southern Turkey.

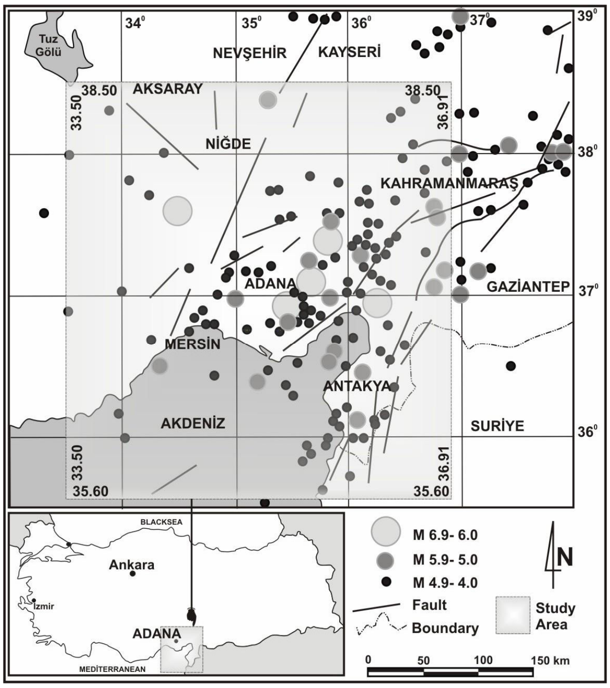

Figure 1: Episanter distributions map of eastern Mediterranean region.
Şekil 1: Doğu Akdeniz bölgesi episantır dağılım haritası.

The seismicity of the research area was investigated by determining the earthquake occurrence number and recurrence periods. The exponential distribution function model was used together with Poisson and Gumbell models and the validity of this model for this kind of a seismicity research was investigated. No seismic risk evaluation studies using exponential distribution model has been found in literature in terms of seismicity. In this respect, this study also presents the application phases of the model in detail.

EVALUATION OF THE MAGNITUDE-FREQUENCY RELATIONS

Soysal et al. (1981) reported that the strongest earthquake in the Çukurova region, which had 7.5 magnitude (intensity, 10), occurred in Antakya (South Turkey) in 245 A.D. Figure 2, illustrates the distribution of 4 magnitude or larger earthquakes versus years which has been prepared to describe the seismic activity of Çukurova region.

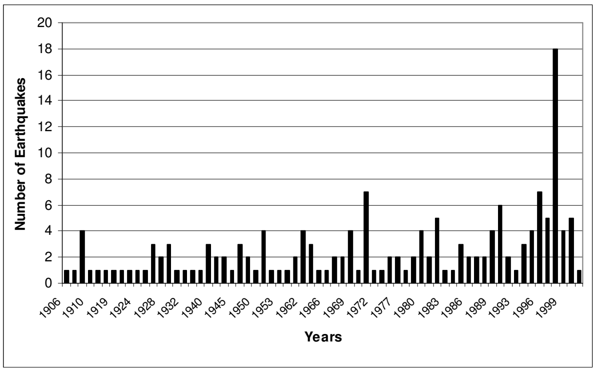

Figure 2: Number of earthquakes changing for the years (1900 - 2001).
Şekil 2: Deprem sayılarının yıllara göre değişimi (1900 - 2001 yılları için).

The basic magnitude-frequency relationship suggested by Gutenberg and Richter (1954) is of great importance, since it is directly related to the an earthquake occurrence. In order to uncover this relationship, 165 earthquakes which have M_s >4 magnitude were investigated in the study area. The number of earthquake occurence was calculated by using 0.1 magnitude interval and normal frequency values are given in Table 1.

$$\text{Log N} = a - bM \qquad (1)$$

In this equation;
N : Cumulative earthquake number
M: Magnitude
a and *b* are the coefficients.

The magnitude-frequency relation for Çukurova region is identified by "Log N= 6.29 – 0.96 M" formula by using the values presented in Table 1 (Figure 3). According to this relation, ***a*** value has been calculated as 6.29 and ***b*** as 0.96. In Gutenberg-Richter function, a big value of ***a*** coefficient points to numerous small earthquakes, whereas a small value of ***b*** coefficient indicates the predominance of big earthquakes. According to this relationship, it can be concluded that small magnitude earthquakes are widespread in the Çukurova region.

Table 1: Magnitude – earthquake frequency relationship.
Çizelge 1: İncelenen depremler için magnitüd – deprem sayıları.

M	*N*	*Total N*	*LogN*
4.0	19	165	2.217
4.1	19	146	2.164
4.2	16	127	2.104
4.3	16	111	2.045
4.4	10	95	1.977
4.5	15	85	1.929
4.6	15	70	1.845
4.7	9	55	1.740
4.8	6	46	1.663
4.9	9	40	1.602
5.0	5	31	1.491
5.1	5	26	1.415
5.2	7	21	1.322
5.3	3	14	1.146
5.4	1	11	1.041
5.5	3	10	1.000
5.6	2	7	0.845
5.7	0	5	0.699
5.8	1	5	0.699
5.9	0	4	0.602
6.0	2	4	0.602
6.1	0	2	0.301
6.2	1	2	0.000
6.3	1	1	0.000
6.4	0	0	0.000

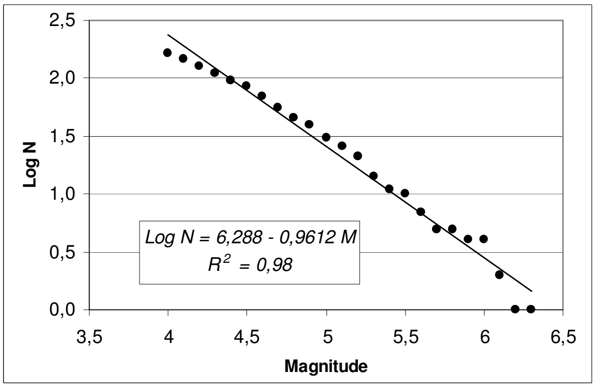

Figure 3: Magnitude – frequency relationship.
Şekil 3: İncelenen veriler için ortaya konulan magnitüd – frekans ilişkisi.

IDENTIFICATION OF SEISMIC RISK USING EXPONENTIAL DISTRIBUTION MODEL

X is assumed to be a random variable having the magnitude value of M. In this study, exponential distribution model of λ and θ parameters were suggested for the X random variable or for magnitude 4.0 and bigger earthquake which occurred in Çukurova region during 1900-2001. The probability density function of X random variable in the form of exponential function is as follows (Ramachandran, 1980);

$$f_M(x) = \lambda e^{-\lambda(x-\theta)} \quad \lambda > 0 \quad \theta \le x < +\infty \qquad (2)$$

The value of λ parameters in exponential probability density function is calculated by the following equation;

$$\lambda = (\bar{x} - \theta)^{-1} \quad (3)$$

where, $\bar{x}$ is the mean magnitude value obtained from many earthquake data and θ stands for the smallest magnitude value. The distribution function of X random variable is found as,

$$F_M(x) = \int_{\theta}^{x} \lambda e^{-\lambda(U-\theta)} dU = 1 - e^{-\lambda(x-\theta)} \qquad \lambda > 0$$
$$\theta \le x < +\infty \quad (4)$$

by utilizing exponential probability density function (Hahn and Shapiro, 1994).

The Chi-Squared Goodness of Fit Test

The Chi-Squared (χ^2) Test, found by Karl Pearson in 1989, depends on the correlation between observing value and expected value of test groups. By means of this test, the distribution of values of two or more groups can be correlated at the same time. In this study, the Chi-Squared Goodness Test was applied for 165 earthquakes observed with a view to to controling the suitability of experimental distribution to theoretical exponential distribution. In the application of the Chi-Squared Goodness Test, the experimental (empirical) distribution function value for each class is compared to theoretical distribution function value obtained from distribution function. If the calculated χ^2 value (χ_h^2) is smaller than χ^2 value (χ_t^2) in table, the hypothesis is considered to be true. Otherwise, the hypothesis is rejected (Hahn and Shapiro, 1994).

The Goodness of Fit Test investigates the validity of the difference between the experimental (empirical) distribution function values and the value of theoretical distribution function obtained from the distribution function. For a similar purpose, the data gathered from the examples related to earthquake numbers were checked to see if they are in accordance with the theoretical exponential distribution or not. For this aim, the following test equation was utilized;

$$\chi^2 = \sum_{i=1}^{k} \frac{(F_{M_g}(O_i) - F_{M_b}(O_i))^2}{F_{M_b}(O_i)} \quad (5)$$

where k is the class number for data, O_i, is the class mid-point value for i^{th} class, $F_{M_g}(O_i)$ is value or cumulative percentage of empirical distribution function observed in class mid-point value for i^{th} class, and $F_{M_b}(O_i)$ is the value of theoretical distribution function expected in class mid-point value for i^{th} class.

A significance level is chosen for the test applied. The validity or rejection of χ^2 Goodness of Fit Test and of hypothesis are confirmed according to this significance level. The Chi-Squared Test significance level is taken as $\alpha = 0.05$ in this study.

Data Analysis

This study analyzed the 4 and bigger magnitude earthquakes that occurred in the area of 36.50° - 38.50° N and 33.50° - 36.91° E coordinates. The total number of earthquakes and their magnitude are presented in Table 2.

Table 2: Earthquake number and magnitude values (f_i) of study area earthquakes.

Çizelge 2: İnceleme alanı için magnitüd değer aralıkları ve bu aralıklarda meydana gelen deprem sayıları.

Magnitude M (x)	Value (f_i)
4.0 – 4.4	80
4.5 – 4.9	54
5.0 – 5.4	21
5.5 – 5.9	6
6.0 – 6.4	4

$\bar{x} = 4.6$ was found by using the following formula;

$$\bar{x} = \left(\sum_{i=1}^{k} O_i f_i\right) \Big/ \left(\sum_{i=1}^{k} f_i\right)$$

$$\bar{x} = \left(\sum_{i=1}^{5} O_i f_i\right) \Big/ \left(\sum_{i=1}^{5} f_i\right) = \frac{758}{165} = 4.6$$

and λ = 2.5 was found by using the following formula, utilizing the data in Table 2;

$$\lambda = (\bar{x} - \theta)^{-1}$$

$$\lambda = (\bar{x} - \theta)^{-1} = \frac{1}{4.6 - 4.2} = \frac{1}{0.4} = 2.5$$

The class mid-point value of first class ($\theta = O_1 = 4.2$) is taken as the smallest value for θ. In this case, the exponential probability density function turns into to the following formula;

$$f_M(x) = 2.5e^{-2.5(x-4.2)} \quad \theta \le x < +\infty$$

X random variable distribution function according to the exponential distribution function used is as follows;

$$F_M(x) = \int_{\theta}^{x} 2.5e^{-2.5(U-4.2)}dU = 1 - e^{-2.5(x-4.2)}$$

$4.2 \le x < +\infty$

Table 3, shows earthquake magnitude intervals, recurrence periods and percentages corresponding to those recurrence periods.

Table 3: Frequency distribution table for constructed classes.
Çizelge 3: Oluşturulan sınıflara ait sıklık dağılım çizelgesi.

Class Num. i	*Class low-point boundary*	*Class mid point value (O_i)*	*Class high-point value*	*Earthquake number (f_i)*	*%*
1	4.0	4.2	4.4	80	0.4848
2	4.5	4.7	4.9	54	0.3273
3	5.0	5.2	5.4	21	0.1273
4	5.5	5.7	5.9	6	0.0364
5	6.0	6.2	6.4	4	0.0242
		Total		165	1.0000

Table 4 illustrates the empirical distribution function values for each class formed according to the 165 earthquake data, and the theoretical distribution function values determined by the distribution function equation. The empirical distribution function values in the table have been calculated by adding the percentages as cumulative. The theoretical cumulative distribution function values presented in Table 4 were calculated by adding the theoretical distribution function values for each class cumulatively.

The appropriacy of the data obtained from 165 earthquakes analyzed in order to develop the model suitability was investigated by means of the Goodness of Fit Test. The Chi-Squared Degree was calculated as χ^2 = 0.0196. The Chi-Squared Table Value was determined as χ_h^2 = 7.8147 according to unconstrained degree 3 and 0.05 significance level (Hahn and Shapiro, 1994). When the calculated and the table values are compared, it is accepted that the empirical distribution conforms to exponential distribution and thus the hypothesis is statistically validated.. Table 5, which used the values of expected cumulative probability, shows the occurrence probability of earthquakes with different magnitudes ($F_M(x)$), annual expected frequency values (F_i) and average recurrence periods per year.

Table 4: Experimental and theoretical distribution functions values for the constructed model.
Çizelge 4: Oluşturulan model için deneysel ve teorik dağılım fonksiyonlarına ait değerler tablosu.

Class Num. i	*Class mid-point value, (O_i)*	*Frequency number (f_i)*	*%*	*Empirical, $F_{M_g}(x)$*	*Theoretical $F_{M_b}(x)$*	*Difference of values*
1	4.2	80	0.4848	0.4848	0.3983	0.0865
2	4.7	54	0.3273	0.8121	0.8310	-0.0189
3	5.2	21	0.1273	0.9394	0.9525	-0.0132
4	5.7	6	0.0364	0.9758	0.9867	-0.0109
5	6.2	4	0.0242	1.0000	0.9963	0.0037

In order to calculate the $F_M(x)$ value in the table, annual number of earthquake > 4 magnitude observed annually is required. For this purpose, the ratio sum of earthquake > 4 magnitude number to examined time periods (100 years) was utilized (1.65). Annual expected recurrence number (F_i values) in Table 5 was determined by multiplying $f_M(x)$ values by annual average observed earthquake numbers observed annually. The average recurrence periods are calculated by means of $1/F_i$ equation (Hahn and Shapiro, 1994). Table 5 shows that the recurrence period of a 4.2 magnitude earthquake as 1.5 years, whereas that of a 6.2 magnitude earthquake, similar to the one occured in Ceyhan-Adana, Turkey in 1998, is estimated as 63 years.

Table 5: Return periods for different classes.
Çizelge 5: Modele ait sınıf değerleri için tekrarlanma periyotları.

Class mid-point value, (O_i)	***Theoretical,*** $F_{M_b}(x)$	$f_M(x)$	F_i	***Average Recurrence Periods (year)***
4.2	0.3983	0.3983	0.6572	1.5216
4.7	0.8310	0.4327	0.7140	1.4006
5.2	0.9525	0.1215	0.2005	4.9872
5.7	0.9867	0.0341	0.0563	17.7589
6.2	0.9963	0.0096	0.0158	63.2367

DETERMINATION OF SEISMIC RISK BY POISSON MODEL

Another frequently used model in estimating earthquake occurence is the Poisson model. According to this model, the distribution of waiting time for another earthquake is not affected by the time after the occurence time of just the previous earthquake (Öztemir et al., 2000). Statistical data shows that the Poisson model is valid especially for big earthquakes. In a study carried out by Kiremidjian et al. (1992), which compared the Poisson and Markov models, it was pointed out that the Poisson model is adequate to estimate earthquake hazard in a region where frequent middle magnitude earthquakes occur. The earthquake parameters for the investigated area for Poisson models have been computed by using the following equations and the results are listed in Table 6.

Table 6: Earthquake parameters for the study area.
Çizelge 6: Çalışma alanı depremsellik parametreleri.

a	***b***	***a'***	A_1	a_1'
6.29	0.96	5.945	4.285	3.941

$$a' = a - \log (b * \ln 10) \quad (6)$$

$$a_1 = a - \log T \quad (7)$$

$$a_1' = a' - \log T \quad (8)$$

In these equations *T,* stands for the investigated time periods and was taken as 100 years. The normal frequency value used to determine seismic risk is found by,

$$N(O_i) = 10^{a_1' - bO_i} \quad (9)$$

equation. $N(O_i)$ value expresses annual average earthquake occurence number which is calculated according to earthquake magnitude and seismic parameters. Seismic risk values ($R(O_i)$) can be determined by the following equation;

$$R(O_i) = 1 - e^{-N(O_i)T^*} \quad (10)$$

Different from the other models, T^* value in this model shows the future time portion to be used in calculating earthquake occurence risk.

According to Poisson model, recurrence period is determined as years using the equation of

$$Q(O_i) = \frac{1}{N(O_i)} \quad (11)$$

Calculated seismic risk values and recurrence periods for the study area are shown in Table 7.

Table 7: Obtained seismic risk and return periods.
Çizelge 7: Çalışma alanı için elde edilmiş sismik risk ve dönüş periyotları.

x (O_i)	$N(O_i)$	*Seismic Risk (%)*							$Q(O_i)$
		Years							
		10	*20*	*30*	*40*	*50*	*75*	*100*	
4.0	1.261	99	100	100	100	100	100	100	0.8
4.2	0.811	100	100	100	100	100	100	100	1.2
4.5	0.418	98	99	100	100	100	100	100	2.4
4.7	0.268	93	99	100	100	100	100	100	3.7
5.0	0.138	75	94	98	99	99	99	100	7.3
5.2	0.089	59	83	93	97	99	99	100	11.2
5.5	0.0458	37	60	75	84	90	97	99	21.8
5.7	0.0294	25	44	59	69	77	89	95	34.0
6.0	0.0151	14	26	36	45	53	68	78	65.9
6.2	0.0097	9	18	25	32	39	52	62	102.6
6.4	0.0063	6	12	17	22	27	38	47	159.6

According to this model, recurrence period for 4.2 and 6.0 magnitude earthquake was found to be 1.23 and 65.92 years, respectively. Occurrence probability of 6.2 magnitude earthquake in 30 years was determined as 36 %. Occurrence probability of earthquake in 100 years time period was calculated by using Poisson model and the results are shown in Figure 4.

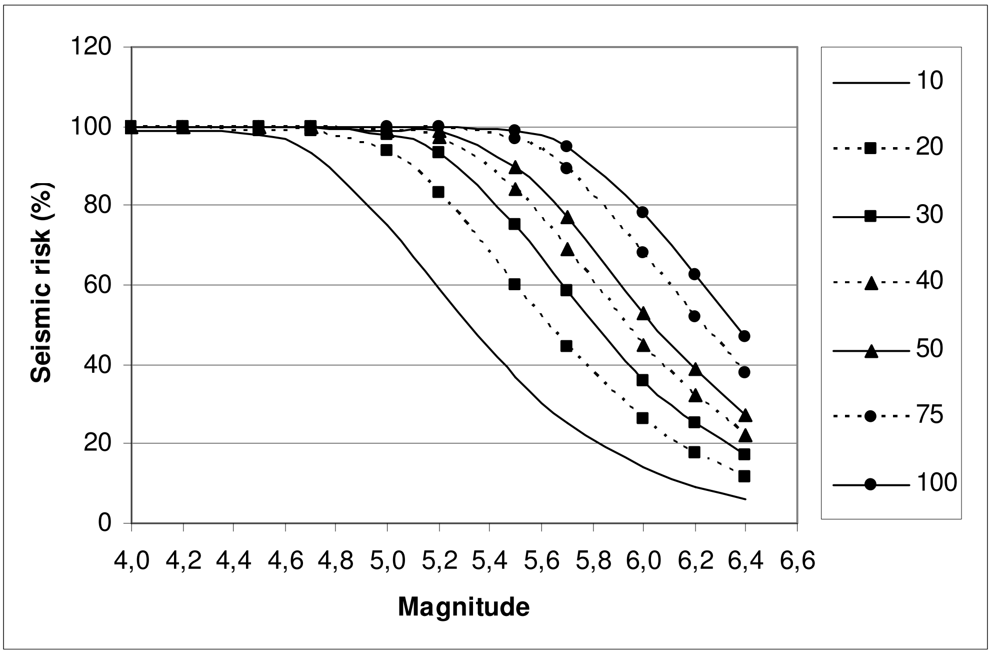

Figure 4: Seismic risk values using Poisson model.
Şekil 4: Poisson modeliyle hesaplanmış sismik risk değerleri

DETERMINATION OF SEISMIC RISK USING GUMBEL MODEL

The Gumbel model defined by Gumbel (1958) depends on the biggest magnitude earthquake in one year. For this reason, the Gumbel model is referred to as "the biggest annuals" method. Distribution function of the method is expressed as the following equation;

$$G(M) = e^{-\alpha . e^{-\beta . M}} \quad (12)$$

where M shows earthquake magnitude, α and β shows regression coefficient depending on seismicity. α and β are calculated by using the following equations;

$$\alpha = 10^{a} \quad (13)$$

$$\beta = b * ln(10) \quad (14)$$

a and ***b*** values were calculated as 4.403 and 1.034 respectively for the study area. Table 9 illustrates the results regarding earthquake recurrence at 0.5 unit (earthquake magnitude) interval and Figure 5 presents these at 0.1 unit interval. Ulutaş et al. (2001) defined the number of earthquake occurrences per year, recurrence period and seismic risk for a neighbouring region by considering 4.0 - 7.0 magnitude earthquakes occured during 1900-1998. Table 8 also summarizes the comparison of the results of this study to those of Ulutaş et al.

Table 8: Seismic risk values using Gumbel model.
Çizelge 8: Gumbel modeli kullanılarak hesaplanmış sismik tehlike parametreleri.

M	*N(M)*		*Recurrence periods, Q(M)*		*Seismic risk value, R(M)*	
4.0	1.8555	*1.1635**	0.5389	*0.8595**	0.8431	*0.6876**
4.5	0.5645	*0.4608**	1.7715	*2.1702**	0.4307	*0.3692**
5.0	0.1717	*0.1825**	5.8230	*5.4797**	0.1574	*0.1668**
5.5	0.0507	*0.0723**	19.141	*13.8361**	0.0507	*0.0697**
6.0	0.0159	*0.0286**	62.917	*34.9362**	0.0157	*0.0282**
6.4	0.0061	-	163.01	-	0.0060	-
6.5	-	*0.0113**	-	*88.2139**	-	*0.0113**

* Ulutaş et al.'s (2001) study results (for earthquakes between 1900 – 1998).
N(M), Annual average earthquake occurence number
(M), Recurrence periods
R(M), Seismic risk value

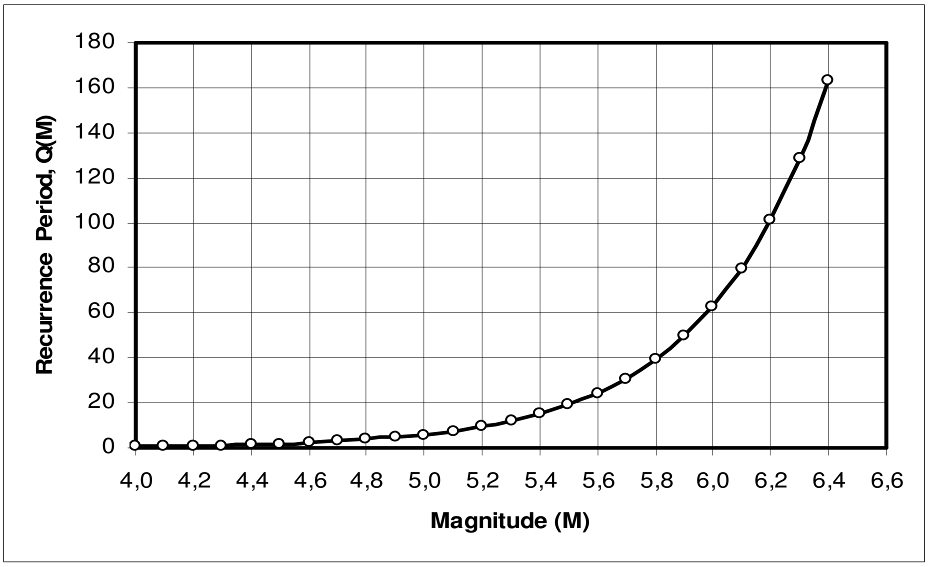

Figure 5: Return period values obtained from using Gumbel model.
Şekil 5: Gumbel modeli kullanılarak belirlenmiş tekrarlanma periyotları.

DISCUSSION

It is seen that the Poisson and Gumbel models give consistent values for this region. As for the annual occurrence number, the exponential distribution function model gives similar values to those of the other models especially for 5.2 and bigger magnitude earthquakes (Figure 6). According to these results, it can be said that exponential distribution function model is not suitable for 5 and smaller magnitude earthquakes. Similarly, when recurrence periods are investigated according to earthquake magnitude, Poisson and Gumbel models give close values but exponential distribution function model produces smaller values of recurrence periods compared to the other models (Figure 7).

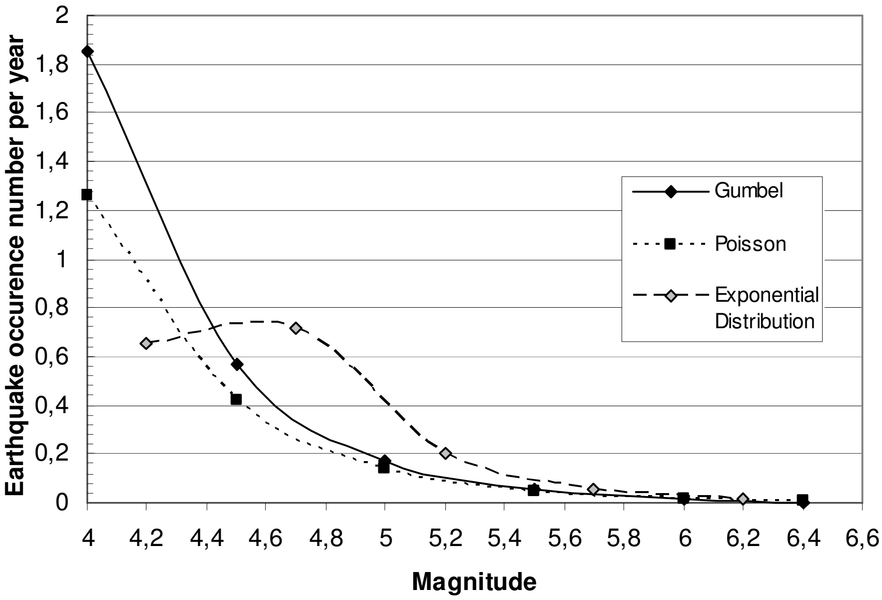

Figure 6: Earthquake occurrence numbers per year according to the models for the different magnitude values.
Şekil 6: İncelenen modellerin farklı büyüklükteki depremler için verdikleri yıllık deprem oluş sayıları grafiği.

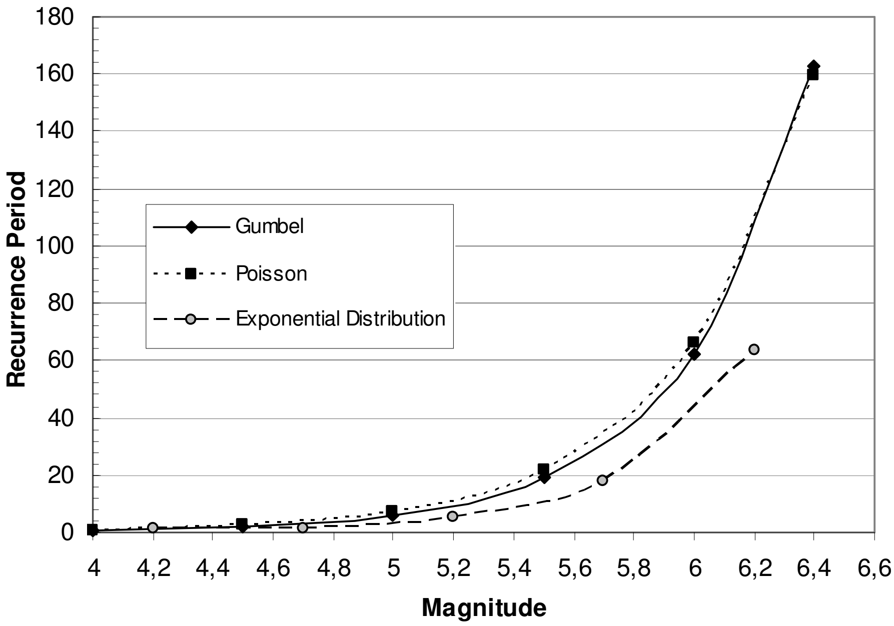

Figure 7: Recurrence periods graphic for different earthquake magnitudes for investigated models.
Şekil 7: İncelenen modeller için farklı büyüklükteki depremlere ait tekrarlanma periyodu grafiği.

CONCLUSIONS

It is known that the analyses using statistical methods give almost correct results for the evaluation of seismic risk analysis when suitable data is used. For this reason, the Poisson and Gumbel models are the methods frequently used in the world.

Magnitude-frequency relation was determined with $Log\ N = 6.29 - 0.96\ M$ formula using earthquake data from the area investigated for this study. In addition, the validity of exponential distribution function model was examined and the consistency of results to other methods was investigated.

The recurrence period of 6.2 magnitude earthquake has been calculated as 63.23 years with the exponential distribution function model, and 102.6 years according to the Poisson models. By contrast, the Gumbel model gave 101.40 years for the same magnitude. The exponential distribution model led to values similar to those computed by using other models in terms of the annual earthquake occurrence with ≥ 5.2 magnitude. It was found out that the exponential distribution model resulted in smaller values than others related to recurrence periods.

It should not be overlooked that the results obtained from this kind of study are directly connected to the distribution amount and total number of the data used. For this reason, active tectonic data of the region should be evaluated very carefully to identify regional limits.

The exponential distribution function model, as well as Poisson and Gumbel models, can be utilized for seismic risk analyses. However, instead of using only one method, the use of different distribution models in combination will be very important to evaluate and interepret the results accurately.

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