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RESEARCH ARTICLE/**ARAŞTIRMA MAKALESİ**

THE ESTIMATION OF EARTHQUAKE RISK IN ESKİŞEHİR

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ABSTRACT

In this study, the earthquakes data which were obtained from Earthquake Investigation Department Directorship of Seismic Division and occurred in the area coordinated 39-40 North and 29-30.5 east (Turkey-Eskişehir) between 1900-1999 and whose magnitudes equal 4.5 or higher were used. For the risk analysis, Weibull distribution with two parameters is used. The parameter estimation of the distribution is calculated through the "less than…" and median order values approaches by using the Least Squares Method (LSM). It is estimated that the probability of the occurrence of the earthquake whose magnitude equals to 4.5 or higher within 10 years is approximately found 0,97.

Key Words: Seismic risk, Weibull distribution, Least squares method

ESKİŞEHİR'İN DEPREM RİSKİNİN TAHMİNİ

ÖZ

Çalışmada Deprem Araştırma Dairesi Sismoloji Şube Müdürlüğü'nden alınan veriler kullanılmıştır. Söz konusu veriler 1900-1999 yılları arasında 39-40 Kuzey ve 29-30.5 Doğu koordinatları arasında yer alan Eskişehir bölgesinde 4.5 ve daha büyük depremlerden oluşmaktadır. Risk analizi için iki parametreli Weibull dağılımı kullanılmıştır. Parametre tahminleri "den az" ve medyan sıra değerleri yaklaşımlarıyla En Küçük Kareler Tekniği kullanılarak hesaplanmıştır. Sonuçta söz konusu inceleme bölgesinde 10 yıl içinde 4.5 ve daha büyük şiddette deprem meydana gelme olasılığı 0,97 olarak tahmin edilmiştir.

Anahtar Kelimeler : Sismik risk, Weibull dağılımı, En küçük kareler tekniği

1. INTRODUCTION

It has been a quarter century since Utsu (1972a, 1972b), Rikitake (1974) and Hagiwara (1974) proposed a probabilistic approach for forecasting the time of the next earthquake on a specific fault. Poisson distribution is applied for seismicty studies (Cornell 1968; Caputo 1974; Shah 1975; Bath 1978; Cluff. et al., 1980). A number candidate statistical distributions have been proposed for computation of conditional probabilistic of future earthquakes, including the Double Exponantial (Utsu, 1972b), Gaussian (Rikitake, 1974), Weibull (Hagiwara, 1974; Rikitake, 1974), Log-normal (Nishenko and Buland, 1987) and Gamma (Utsu, 1984), Pareto (Sergio, 2003) distributions. The difficulty lies in determining the correct distribution, given data of large seismic event on a given faults. Nishenko and Buland (1987) obtained a reasonably good fit to a log-normal distribution. Mc Nolly and Minster (1981) have argued that a Weibull distribution is more appropriate.

Nowadays, the possibility of existence of earthquakes can be estimated with the help of various distributions. In order to model the processes through different distributions and make the parameter estimations, the place, magnitude, scale and occurrence time

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of the earthquake should be known. With the help of these parameters, seismic risk analysis can be made by a statistical approach. The interpretation of the analysis made is possible through the earthquakes recorded and occurred in the past (Yücemen, 1982).

In this study, the earthquakes which were obtained from Earthquake Investigation Department Directorship of Seismic Division and occurred in the area coordinated 39-40 North and 29-30, 5 East (Turkey-Eskişehir) between 1900-1999 and whose magnitudes equal 4, 5 or higher were used. With the data set obtained, the estimation parameters of Weibull distribution were estimated by using LSM and a risk analysis was made for the region located on the above-mentioned coordinates in Eskişehir.

2. METHOD

If we accept that T is the Weibull random variable with the parameters α andβ, the probability density function of T is;

$$f(t;\alpha,\beta)=\beta\alpha^{-\beta}t^{\beta-1}\exp(-\alpha^{-\beta}t^{\beta}) \qquad t>0, \alpha>0, \beta>0$$
(1)

In the equation (1), α is scale parameter and β is form parameter. Cumulative distribution function of Weibull distribution with two parameters is expressed as follows:

$$F(t)=1-\exp(-\alpha^{-\beta}t^{\beta}) \text{ , t>0} \qquad \textbf{(2)}$$

Reliability function of Weibull distribution with two parameters is defined as follows:

$R(t)=1-F(t), \quad t>0$

$$R(t)=\exp(-\alpha^{-\beta}t^{\beta}) \text{ , } t>0 \qquad \textbf{(3)}$$

The hazard function obtained through the ratio of the probability function by reliability function is as follows:

$$h(t)=\frac{f(t)}{R(t)}=\beta\alpha^{-\beta}t^{\beta-1} \qquad \textbf{(4)}$$

The expected value of Weibull distribution with two parameters is;

$$E(T)=\alpha\Gamma(\frac{1}{\beta}+1) \qquad \textbf{(5)}$$

One of the techniques used in the parameter estimation of Weibull distribution is LSM

Cumulative distribution function can be experss as a linear regression model as follows:

$$F(t)=1-\exp(-\alpha^{-\beta}t^{\beta})$$

$$\frac{1}{1-F(t)}=\exp(\left(\frac{t}{\alpha}\right)^{\beta})$$

$$\ln\{\ln[1-F(t)]^{-1}\}=\beta\ln t-\beta\ln\alpha$$

If $y=\ln\{\ln[1-F(t)]^{-1}\}$ and $x=\ln t$, then

$$y=\beta x-\beta\ln\alpha \qquad \textbf{(6)}$$

And this is nothing but a linear regression equation of a= β and b= $-\beta\ln\alpha$ from y=ax+b+e_i. In the last equation, there is a linear relationship between x and y. With the help of this present relationship, the parameters of Weibull distribution are estimated by using the LSM (M. Fawzan, 2000).

By using the earthquakes data which were obtained from Earthquake Investigation Department Directorship of Seismic Division and occurred in the area coordinated 39-40 North and 29-30,5 East (Turkey-Eskişehir) between 1900-1999 and whose magnitudes equal 4,5 or higher, the values of shape and scale parameters of Weibull distribution were estimated through the LSM that were applied by two different approaches. The rational variable in the study was defined as the time (year) between the two earthquakes occurred successively, which had a 4, 5 magnitude or higher between 1900 and 1999 within the area limited by the coordinates of 39-40 North and 29-30, 5 East. In order to do the analysis through Weibull distribution, the occurrence time of the earthquakes that equal or higher a certain magnitude is determined form the data set. Section number is shaped with the successive two-year-old classification of the data. By taking the "i" time period as 2, the frequency values of the earthquakes occurred at this intervals were discovered. In order to put forward the presence of a linear relationship, by using the numbers of earthquake occurred between "$t_i - t_{i+2}$" time sequence, probability functions were calculated by the linear relationship defined in equation 3 and data set was made available for the use of LSM. Applying LSM to the obtained transformation values obtained, two different approaches were used. The obtained parameter estimations were presented in the following subsections:

2.1. Parameter Estimations by Using the Cumulative Frequencies

In the first approach, frequency values each of which are related to "$t_i - t_{i+2}$" time sequence are compared with total frequency values and cumulative frequencies are obtained. The cumulative frequencies obtained were defined as F (t) and logarithmic transformations for these values were done.

For the time sequences, upper limit values were taken instead of middle points; because, when we analyse the frequency distribution arranged through observed values, it can be seen that the case was better represented by the upper limit values and the observations in each interval are collected on the end limit value. As a result of using “F (t)”, the observed value of cumulative frequencies has been lost. This can be seen form the Table 1 below:

Table 1. Obtaining the X and Y Values through Cumulative Transformation Values

Observed Cmul.Freq.	t	Y=ln{-Ln(1- t)}	X= ln (t)
0,8824	2	0,7608	0,6931
0,9294	4	0,9749	1,3863
0,9529	6	1,1172	1,7918
0,9647	8	1,2072	2,0794
0,9765	10	1,3216	2,3026
0,9882	12	1,4913	2,4849
0,9882	14	1,4913	2,6391
0,9882	16	1,4913	2,7726
0,9882	18	1,4913	2,8904
0,9882	20	1,4913	2,9957
0,9882	22	1,4913	3,0910
1,0000	24		

As a result of the linear relationship between the transformations values shown in Table 1, the estimation of Weibull distribution parameter values are gained through LSM. The shape parameter is found $\hat{\beta}$ = 0, 3359, scale parameter is found $\hat{\alpha}$ =0, 2033, and with the help of equation (5), the repetition period of the concerned case is found as E ($\boldsymbol{t}$) =1, 19. After the estimation of repetition period, the risk values for Eskişehir region can be determined on the different conceiving periods that will be defined. Risk values are estimated by the cumulative distribution function of Weibull distribution. For different periods, $\boldsymbol{t}_i$ is defined as $\boldsymbol{t}_i$: 5, 10, 20, 30, 50 and 100 and the results are given in Table 2.

Table 2 The Risk Values Found for Different Conceiving Periods

Conceiving Period (year)	5	10	20	30	50	100
P	0,9467	0,9753	0,9906	0,9953	0,9983	0,9997

The obtained linear equation from LSM is $\hat{y}$ =0, 335955 $\boldsymbol{x}$ + 0535364.

The meaningfulness coefficients of the equation obtained and R^2 determination coefficient are given in Table 3 and their graphics are in Figure 1.

Table 3. Regression Coefficients and their Meaningfulness

	Coefficients	Standard Error	t value	P (Sign.)
a	0,335955	0,025279	13,290	0,000
b (constant)	0,535364	0,060466	8,854	0,000
R^2 =0,95151				

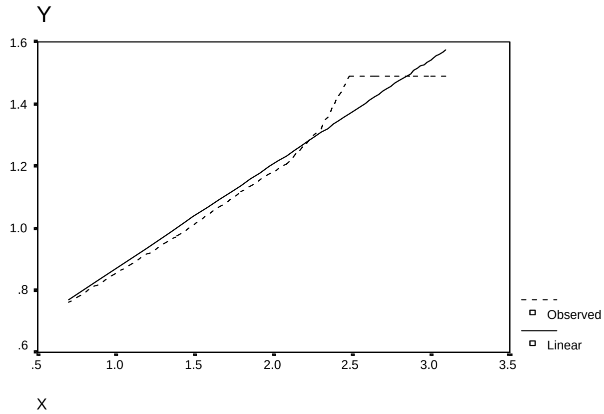

Figure 1. Observed Values and Obtained Linear Model

2.2. Parameter Estimations by Using the Median Order Values

In the second approach, while applying LSM to transformation values, instead of “less than…” cumulative frequencies, median order values are used and an observed value that was lost in the first method has been saved in this method.

Median Order Values are calculated by the following equation:

$$MR\% = \frac{i - 0{,}3}{n + 0{,}4} * 100 \qquad \textbf{(7)}$$

In the equation (7) above, i shows the order and n=85 shows the total observation number. The values obtained as a result of LSM application related to this issue are given in Table 4.

Table 4. Obtaining the Median Order Values

F(t)	t	Median order values	Y=ln{-ln(1-(MR)}	X=ln(t)
75	2	0,8747	0,7310	0,6931
79	4	0,9215	0,9342	1,3863
81	6	0,9450	1,0646	1,7918
82	8	0,9567	1,1439	2,0794
83	10	0,9684	1,2396	2,3026
84	12	0,9801	1,3653	2,4849
85	24	0,9918	1,5695	3,1781

Taking the Median Order Values into account, the shape parameter estimation value obtained from LSM is found 0, 3428 while estimation value of scale parameter is 0, 2557. Repetition period is 1, 38 years. For different periods $\boldsymbol{t}_i$: 5, 10, 20, 30, 50 and 100 estimated risk values;

Table 5. Risk Values for Different Construction Periods.

Construction Period (year)	5	10	20	30	50	100

P	0,9375	0,9703	0,9885	0,9941	0,9978	0,9996

3. RESULT

In this study, by using the cumulative "less than…" and median order values, estimations of Weibull distribution parameters are obtained. Consequent to two different approaches, it was observed that shape and scale parameters of Weibull distribution had very close values to each other.

In the study, when at the risk values obtained through the estimated parameters, for different construction values of the possibility of the occurrence of the earthquakes which magnitudes equal to 4,5 or higher within the limited area of 39-40 North and 29-30,5 East are given in Table 2 and Table 5 as possibility values.

In Eskişehir region, the probability of the occurrence of the earthquake which magnitude equals to 4,5 or higher within 10 or more than 10 years is found 0,97. This value cannot be disregarded. For this reason, those concerned and administrators should take into consideration this issue in their plans, programmes and predidtions for the future.

4. DISCUSSION

In the study, there is a point of view created by using only Weibull distribution in the seismic risk analysis. The results obtained through different theoretical distributions can be varied. In order to model the data set in the seismic risk analysis, Poisson, Gumbel and Semi-Markov theoretical distributions can also be used. Here, the important issue is the consistency and continuity of the results for the region modelled. This continuity includes taking the precautions with regards to the founded risk values for different time periods and strengthening the buildings in the region under consideration. In May studies made by using the seismic risk analysis, it is known and asserted that the best theoretical distribution which models the process is Weibull distribution (Işıkara, 1984).

In the estimation of Parameters of Weibull Distribution, The Maximum Likelihood Method and Moments Method can be also used. However, for different sample sizes these techniques effect the parameter estimations of theoretical distribution studied. In this study, in the subtitle of the technique we used results of analysis have given values close to each other and in the analysis made by using "Median Order Values" the analysis is made without the loss of a observed value. Besides providing an analysis without any information loss, the effectiveness of this technique can be compared with other techniques.

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