Associate Professor Irina-Maria DRAGAN, PhD
Professor Alexandru ISAIC-MANIU, PhD
E-mail: irina.dragan@csie.ase.ro
The Bucharest Academy of Economic Studies

CHARACTERIZING THE FREQUENCY OF EARTHQUAKE INCIDENCE IN ROMANIA

Abstract. *From a seismic point of view, Romania is dominated of events in one region, Vrancea. In the past 300 years, a single major seismic event occurred with an epicenter outside this area (1916). This paper starts from going over all major seismic events, with a magnitude of over 6 degrees on Richter's scale, which were documented. Was tested the most plausible statistic behavioral model and was determined the probabilities for future large scale earthquakes, by different time horizons.*

Key Words: *seismic risk, statistic model, modeling, validation, statistic prediction, statistic distribution.*

JEL Classification: C52, C13, C46, Q54

1. GENERAL ASPECTS

As it is well-known, the occurrence of major seismic phenomena is a "rare event" from a statistical point of view. Due to the very large time horizon that can be taken into observation as against to registering events in artificial systems, as well as the non-periodicity of these events, there is the possibility of interpretation and statistical modeling of these seismic phenomena. In Romanian: Dragomir (2009), Lungu (1999), Lungu and Arion (2000), Radulescu (2004).

The statistical studies regarding the earthquakes usually start from the fact that rare events are best described using the exponential law – if considering the succession of time intervals between events, or Poisson's law – if it is intended to model the frequency of earthquakes (Săcuiu and Zorilescu, 1978; Johnson, Kotz and Balakrishnan, 1994; Evans, Hasting and Peacock, 2000).

The easiness of using these two distribution laws, distinct in nature, consists of the fact that they are defined by the same parameter, characterizing the same phenomenon – the behavior of a system in time, from both continuous and discrete points of view. A previous study made on seismic phenomena in Romania (Voda and Isaic-Maniu, 1983) covering the time period 1400-2000, has failed to confirm the hypothesis of an exponential behavior, the confirmed model being the bi-parametric Weibull model.

In the followings, we shall extend the area of investigation starting with the year 1100, with some additions to the identified supplementary information, as well as to the earthquake in 1977, the last one taken into account in the previous study.
We considered major seismic events those with a level of over 6 degrees on Richter's scale. Obviously, historical assessments are somewhat subjective, as the intensity was evaluated indirectly, since Mercalli (1931) and Richter's (1956) scales are more recent. The chronicles used to register that: "the earth had been shaken and the bells were ringing by themselves in Golia's tower" (n.n. Iasi – Romania), which indicates that an important seismic event took place. We used information in the profile literature (Constantinescu and Marza, 1980) as well as other official sources as those of the National Institute for the Physics of Earth (www.infp.ro).

2. THE OCCURRENCE OF MAJOR SEISMIC EVENTS

The main seismic events which occurred in Romania, and their characteristics, as they were recorded at the time in documents, or in modern and official registrations, were:

- November 5th, 1107, 6.2 degrees Richter
- August 8th, 1126, 6.2 degrees Richter
- April 1st, 1170, 7.0 degrees Richter
- February 13th, 7.0 degrees Richter
- May 10th, 1230, 7.1 Richter
- year 1276, 6.5 degrees Richter
- year 1327, 7.0 degrees Richter
- October 10th, 1446, 7.3 degrees Richter
- August 29th, 1471, 12 o'clock, 7.1 degrees Richter. This earthquake took place not long before the wedding of Stefan the Great, sovereign of Moldova, with Maria of Mangop, and it was described by chronicler Grigore Ureche: "while Stefan the Great sat at the table in the Citadel of Suceava, a wing in Nebuisei Tower fell crumbling down."
- November 24th, 1516, 7.2 degrees Richter
- July 19th, 1545, 6.7 degrees Richter
- November 2nd, 1558, 6.1 degrees Richter
- August 17th, 1569, 6.7 degrees Richter
- May 10th, 1590, 6.5 degrees Richter
- August 10th, 1590, 6.1 degrees Richter
- August 4th, 1599, 6.1 degrees Richter
- May 3rd, 1604, 6.7 degrees Richter
- November 24th 1605, 6.7 degrees Richter
- January 13th, 1606 6.4 degrees Richter
- October 8th, 1620, 10:55, 7-8 degrees Richter (some sources indicate 7.9).

The most active area in Romania, seismic wise, is Vrancea, and the shock waves affect the South and South-East areas of Romania, including the capital, Bucharest (Radulian, 2004; Lungu, Arion, Baur and Aldea, 2000; Ivan, 2007; Ardeleanu, 1999; Constantinescu and Mârza, 1980; www.incerc2004.ro).

Urban areas in that time were very few and quite primitive, so that material damages were minor. The buildings affected from this earthquake were churches and monasteries, the only ones which were more considerable.

- August 9th, 1679, 6.8 degrees Richter
- August 8th, 1681, 6.7 degrees Richter
- June 12th, 1701, 7.1 degrees Richter
- October 11th, 1711, 6.1 degrees Richter
- May 31st, 1738, 7.0 degrees Richter – during the reign of Constantine Mavrocordat. In a Greek recording there is also mention of "a terrible earthquake" and in a church book another recording state that on May 31st, at 3 o'clock in the morning there was an earthquake and "earth has opened and water came out with a smell of gun powder and sulfur".
- December 7th, 1746, 6.5 degrees Richter
- year 1750, 6.0 degrees Richter
- January 18th, 1778, 6.1 degrees Richter
- March 18th, 1784, 5.8 degrees Richter
- April 6th, 1790, 7-8 degrees Richter
- December 8th, 1793, 6.1 degrees Richter
- October 26th, 1802, 12:55 PM, 7.9 degrees Richter, depth of 150 km – in Bucharest, the earthquake lasted for 2 minutes and a half, the chronicles and church recordings state that "the towers of the holy churches fell, and other churches fell entirely" and also that in Bucharest "the high tower of Coltea, the wonder of the city, was broken, and few of the mansions and public constructions made it soundly"…and also, many of the wooden houses in Bucharest were burnt. The tower was built between 1709-1714 as observance point (50 m high) and the belfry of Coltea monastery. At its construction, the royal troops of Carol XII of Sweden participated, as they were retreating from the battle of Poltava in the War of the North (June 27-July 8, 1709).
- March 5th, 1812 (2:30 AM) 6.5 degrees Richter, 130 km in depth.
- January 5th, 1823, 6.0 degrees Richter
- November 26th, 1829 (8:45 PM), 7.5 degrees Richter, 150 km in depth, 1 minute duration, the deacon of Batistea church wrote: "it was almost as the earthquake in 1802, October".
- October 15th, 1834, 6.0 degrees Richter
- January 23rd, 1838, 8:45 PM, 7.5 degrees Richter, 150 km in depth (the police prefect's report states that there were 8 people dead, 14 injured, 36 houses entirely damaged, and many with serious damages). The Coltea tower was almost completely destroyed, and was demolished in 1888 when the boulevard was modernized. Later on, the subway works in the 1970s highlight the foundation, marked by marble flagstones engraved in the asphalt, but covered later, at repairs made in the road.
- October 15th, 1847, 6.2 degrees Richter
- October 17th, 1859, 6.0 degrees Richter
- April 27th, 1865, 6.4 degrees Richter
- November 13th, 1868 6.0 degrees Richter
- November 23rd, 1868, 6.5 degrees Richter

- November 26th 1868, 6.1 degrees Richter
- October 10th, 1879, 6.2 degrees Richter
- August 31st, 1894, 7.1 degrees Richter (during this earthquake the riversides of Prut river were damaged on a length of over 500 meters in the county of Galati, and many old houses in the suburbs of Bucharest were also considerably damaged)
- September 13th, 1903, 6.3 degrees Richter
- October 6th, 1908 (11:40 PM), 7.1 degrees Richter, 125 km in depth – it was an earthquake which manifested in 3 consecutive phases, more and more powerful, and lasted approximately 3 minutes. It damaged especially the old houses in Bucharest, in the East of Muntenia and the South of Moldova.
- May 25th, 1912, 6.3 degrees Richter
- January 26th, 1916, 6.4 degrees Richter
- March 29th, 1934, 6.9 degrees Richter
- November 10th, 1940 (1:39 AM). It had a magnitude of 7.7 degrees Richter, 133 km in depth. The effects were devastating in the center and South of Moldova, as well as in Muntenia. The number of the victims was estimated to 1000 deaths and 4000 injured most of them in Moldova. Due to the context created, the exact number of casualties was never known, the information being censured during the war. In Bucharest, many other apartment buildings were considerably damaged. The Carlton construction was destroyed in that occasion, an architectural pride in the Bucharest of the time, the highest construction at the time, placed at the intersection of Royal Street and Bratianu Boulevard (Balcescu Boulevard nowadays). The contemporaries say that no one was salvaged from the approximately 300 persons found in the building. Among the dead, there was also I. Vasilache, famous composer and singer at the time, member of the musical and comedian couple Stroe and Vasilache.
- March 4th, 1977 (9:22 PM), 7.4 degrees Richter, 94 km in depth – lasted approximately 55 seconds, and caused 1578 victims, of which 1424 in Bucharest. At the level of the entire country, there were around 11.300 injured, and approximately 35.000 crashed houses. Most of the material damages were concentrated in Bucharest, were over 33 constructions and large buildings were collapsed. The entire Zimnicea town was destroyed, and needed rebuilding from the ground. Among the victims of the earthquake there were some notorious persons such as the actor Toma Caragiu.
- August 30th, 1986 (12:28 AM), 7.1 degrees Richter, 131.4 km in depth – produced many damages in Basarabia, 4 apartment buildings collapsed in Chisinau.
- May 30th, 1990 (1:40 PM) 6.9 degrees Richter, 80-90 km in depth – didn't cause major damages;
- October 27th, 2004 (10:34 PM) 6.0 degrees Richter, 90-100 km in depth – also, didn't cause major damages.

In the area of Vrancea (analyses of the area in Ivan, 2007; Ivan, 2011; Ardelean, 1999) there are registered almost daily earthquakes under 3 degrees.

3. STATISTIC PROCESSING OF DATA ON MAJOR SEISMIC EVENT

The registered data were processed firs of all, statistically descriptive. The results as distribution series are presented in Table 1, the grouping being done in intervals of 50 years.

Table 1 - The distribution of major seismic events in 50 years intervals

No.	Interval(years)	Number of major seismic events
1	1100 - 1150	2
2	1150 - 1200	2
3	1200 - 1250	1
4	1250 - 1300	1
5	1300 – 1350	1
6	1350 – 1400	0
7	1400 – 1450	1
8	1450 – 1500	1
9	1500 – 1550	2
10	1550 – 1600	5
11	1600 – 1650	5
12	1650 – 1700	2
13	1700 – 1750	5
14	1750 – 1800	4
15	1800 – 1850	7
16	1850 – 1900	8
17	1900 – 1950	7
18	1950 – 2000	4
19	2000 -	1
	TOTAL	n = 59

The series (Table 1 and Figure 1) seems to suggest an acceleration of events in the last 250 years: in the first decade D_1 one earthquake was registered; $Q_2(M_e) = 2$ earthquakes, and in $D_q - 7$. This could be the effect of an energetic acceleration in the intensity of the activity of the terrestrial crust, but most probably it is the result of information inconsistencies in the medieval period which seem to suggest this seismic intensification. The maximum value in an interval of 50 years is 8 major seismic events (1850 – 1900). The total number of major earthquakes is 59. The average in a 50 year interval is 3.11, with a standard deviation of σ = 2,45 and a variation coefficient of CV = 0,788 which suggests a strong heterogeneity of the observation series. Standard error = 0.561.

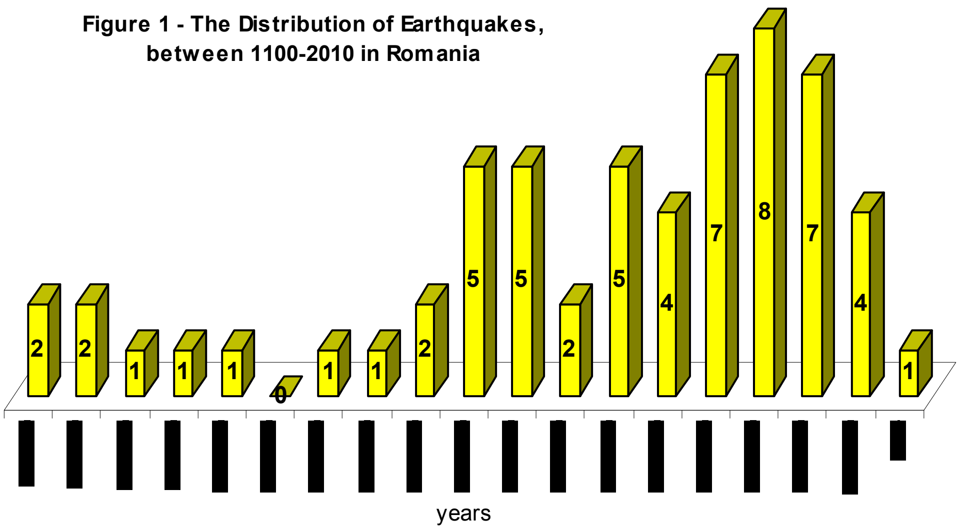
The shape of the series is completed with the values of the Skewness coefficient: $\hat{\beta}_1 = \frac{\mu_3}{\left(s^2\right)^{3/2}}$ (where μ_3 is the centered moment of rank 3, and s^2 – the centered moment of rank 2), and respectively $\hat{\beta}_2$ - Kurtosis coefficient: $\hat{\beta}_2 = \frac{\mu_4}{\left(s^2\right)^2}$ (where μ_4 is the centered moment of rank 4).

$\hat{\beta}_1 = 0.7031$

$\hat{\beta}_2 = -0.7794$

Although it is considered that seismic events are "rare events" from a statistical point of view, thus with reduced probabilities of occurrence, this hypothesis is not confirmed for Romania (Figure 1).

Figure 1 - The Distribution of Earthquakes, between 1100-2010 in Romania



The minimum value in a 50 year interval was 0 (1350-1400), and the maximum number of earthquakes – 8 - was registered between 1850 and 1900. The value of the second quartile was 2, and Q_1 = 1 and Q_3 =5 respectively.

4. STATISTIC MODELING OF THE SEISMIC OCCURRENCE PROCESS

In order to analyze the process of earthquake occurrence, we tested several distribution laws, obviously starting with "the law of rare events" – Poisson, continuing with the exponential law (Evans, 2000) and Weibul (Isaic-Maniu, 1983). The best results were obtained for the log-logistic statistic model (Johnson, Kotz and Balakrishnan, 1995; Evans and Hastings, 2000; Stephens, 1979; Paiva, 1984; Ahmad, Sinclair and Werritty, 1988) by filtering three different selection tests. The statistic literature contains various forms of this model with different degrees of complexity. Thus, a variant has:

Parameters Distribution

β - Continuous shape parameter $(\beta > 0)$

α - Continuous scale parameter $(\alpha > 0)$

γ - Continuous location parameter $(\gamma \equiv 0$ yields the two-parameter Log-Logistic distribution)

Domain

$\gamma \leq x + \infty$

Three-Parameter Log-Logistic Distribution

Probability Density Function (PDF)

$$f(x) = \frac{\beta}{\alpha}\left(\frac{x-\gamma}{\alpha}\right)^{\beta-1}\left(1+\left(\frac{x-\gamma}{\alpha}\right)^{\beta}\right)^{-2} \tag{1}$$

Cumulative Distribution Function (CDF):

$$F(x) = \left(1+\left(\frac{\alpha}{x-\gamma}\right)^{\beta}\right)^{-1} \tag{2}$$

In the case that $\gamma = 0$ the probability density of this **bi-parametric model** is:

$$f(x:\alpha,\beta) = \frac{(\beta/\alpha)(x/\alpha)^{\beta-1}}{\left[1+(x/\alpha)^{\beta}\right]^2} \tag{3}$$

where $x > 0$, $\alpha > 0$, $\beta > 0$ and CDF:

$$F(x:\alpha,\beta) = \frac{1}{1+(x/\alpha)^{\beta}} = \frac{(x/\alpha)^{\beta}}{1+(x/\alpha)^{\beta}} = \frac{x^{\beta}}{\alpha^{\beta}+x^{\beta}} \tag{4}$$

The k^{th} raw moment exists only when $k < \beta$, when it is given by

$$\mathrm{E}(X^k) = \alpha^k \mathrm{B}(1-k/\beta, 1+k/\beta) = \alpha^k \frac{k\pi/\beta}{\sin(k\pi/\beta)} \tag{5}$$

where $\mathrm{B}(\cdot)$ is the beta function. Expression for the mean, variance, Skewness and Kurtosis can be derived from this. Writing $b = \pi/\beta$ for convenience, the mean is

$$E(X) = \alpha b/\sin b, \quad \beta > 1, \tag{6}$$

and the variance is

$$\mathrm{Var}(X) = \alpha^2\left(2b/\sin 2b - b^2/\sin^2 b\right), \quad \beta > 2. \tag{7}$$

Explicit expressions for the Skewness and Kurtosis are lengthy. As β tends to infinity the mean tends to α, the variance and Skewness tend to zero and the excess Kurtosis tends to 6/5 (see also related distributions below).

The quantile function is:

$$F^{-1}(p;\alpha,\beta) = \alpha\left(\frac{p}{1-p}\right)^{1/\beta} \tag{8}$$

The log-logistic has been used as a simple model of the distribution of wealth or income in economics, where Gini coeffcient is $1/\beta$ (Kleiber and Kotz, 2003) it is known as the Fisk distribution. The log-logistic distribution provides one parametric model for survival analysis. The survival function is

$$S(t)=1-F(t)=\left[1+(x/\alpha)^{\beta}\right]^{-1} \tag{9}$$

and so the hazard function is

$$h(t)=\frac{f(t)}{S(t)}=\frac{(\beta/\alpha)(x/\alpha)^{\beta-1}}{1+(x/\alpha)^{\beta}} \tag{10}$$

Generalized log-logistic or the **three parameter log-logistic** distribution. It has also been called the **generalized logistic** distribution (Hosking, 1997), but this conflicts with other uses of the term. It can be obtained from the log-logistic distribution by addition of a shift parameter γ: if *X* has a log-logistic distribution then $X+\delta$ has a shifted log-logistic distribution. So *Y* has a shifted log-logistic distribution if $\log(Y-\delta)$ has a logistic distribution. The shift parameter adds a location parameter to the scale and shape parameters of the (unshifted) log-logistic. In this parameterization, the cumulative distribution function (cdf) of the shifted log-logistic distribution is

$$F(x;\mu,\sigma,\xi)=\frac{1}{1+\left(1+\frac{\xi(x-\mu)}{\sigma}\right)^{-1/\xi}} \tag{11}$$

for $1+\xi(x-\mu)/\sigma\geq 0,$ where $\mu\in\mathbf{R}$ is the location parameter, $\sigma>0$ the scale parameter and $\xi\in\mathbf{R}$ the shape parameter. Note that some references use $k=-\xi$ to parameterize the shape.

The probability density function (pdf) is

$$F(x;\mu,\sigma,\xi)=\frac{\left(1+\frac{\xi(x-\mu)}{\sigma}\right)^{-(1/\xi+1)}}{\sigma\left[1+\left(1+\frac{\xi(x-\mu)}{\sigma}\right)^{-1/\xi}\right]^{2}} \tag{12}$$

again, for $1+\xi(x-\mu)/\sigma\geq 0.$

The shape parameter ξ is often restricted to lie in [-1,1], when the probability density functions is bounded. When $|\xi|>1,$ it has an asymptote at $x=\mu-\sigma/\xi$. Reversing the sign of ξ reflects the pdf and the cdf about $x=0.$

See also:

when $\mu=\sigma/\xi,$ the shifted log-logistic reduces to the log-logistic distribution.

when $\xi\to 0,$ the shifted log-logistic reduces to the logistic distribution.

The shifted log-logistic with shape parameter $\xi=1$ is the same as the generalized Pareto distribution with shift parameter $\xi=1$.

5. VALIDATING THE DISTRIBUTION

In order to test the statistic nature of the distribution, we used the Kolmogorov-Smirnov, Anderson-Darling and Pearson-Fisher tests (Stephans, 1979; www.mathwave.com; www.vosesoftware.com).

Kolmogorov-Smirnov

The test is defined for the hypothesis
H_0: the distribution of earthquakes is log-logistic
H_1: the distribution of earthquakes is not log-logistic.
We compute the empirical distribution function $\hat{F}(x)$:

$$\hat{F}(x) = \frac{1}{n}\sum_{i=1}^{n} I_{X_{i\le x}} \tag{13}$$

where $I_{X_{i\le x}}$ is the indicator function, equal to 1 if $X_i \le x$ and equal to 0 otherwise.
The Kolmogorov-Smirnov statistic for a given cumulative distribution function $F(x)$ is

$$D_n = \sup_x \left|\hat{F}(x) - F(x)\right| \tag{14}$$

and F(x) the theoretical values of distribution.
The D_n computed value is compared to the maximum admitted equivalent.
The statistic computed value for the presented case resulted in $D_n = 0{,}1941$ is inferior to the critical level 0.3612 for a significance level of $\alpha = 0{,}01$.
The Anderson-Darling test – is also a distance test, proposed by Wilbur Anderson and Donald A. Darling in 1952.
The statistic of the test is

$$A^2 = -N - S \tag{15}$$

where:

$$S = \sum_{i=1}^{n} \frac{(2i-1)}{N}\left[\ln F(X_i) + \ln\left(1 - F(X_{n+1-i})\right)\right] \tag{16}$$

in which F is the cumulative distribution function. For a significance level α, we validate one of the two hypotheses H_0 and H_1. The critical values for various specified distributions are computed by Stephens (1979).
The value of the statistics of the test: 2.5023 confirms the log-logistic distribution for $\alpha = 0{,}01$.

Pearson-Fisher Statistic

Chi Square or Pearson-Fisher (χ^2) test was proposed as a measure of random departure between observation and the theoretical model by Karl Pearson (Pearson, 1900). The test was later corrected by Ronald Fisher trough decrease of the degrees of freedom by a unit (decrease duet of the existence of the equality relationship between the sum of observed frequencies and the sum of theoretical frequencies, (Fisher, 1922)), and by the number of 692 unknown parameters of the theoretical

distribution when they come as estimated from measures of central tendency (Fisher, 1924).
The chi-square test is used to test if a sample of data came from a population with a specific distribution. An attractive feature of the chi-square goodness-of-fit test is that it can be applied to any uni-variate distribution for which you can calculate the cumulative distribution function. The chi-square goodness-of-fit test is applied to binned data (i.e., data put into classes).
The test is defined for the hypothesis
H_0: The data follow a specific distribution
H_1: The data do not follow the specific distribution
The statistic is calculated as (in original):

$$\chi^2 = S\left\{\frac{(x-m)^2}{m}\right\} : \chi^2 = \sum_{i=1}^{k}\frac{(O_i - E_i)^2}{E_i} \tag{17}$$

where O_i is the observed frequency for bin i and E_i is the expected frequency for bin i and is calculated by

$$E_i = N(F(Y_u) - F(Y_i)) \tag{18}$$

where F is the cumulative distribution function and Y_u and Y_i are the upper and lower limits for class i.
The test statistic follows, approximately, a chi-square distribution with *(k - c)* degrees of freedom where k is number of non-empty cells and c - the number of estimated parameters for the distribution +1.
Therefore, the hypothesis that data are from a population with the specified distribution is rejected if

$$\chi^2 > \chi^2_{\alpha,k-c}$$

where $\chi^2_{\alpha,k-c}$ is the chi-square percent point function with k - c degrees of freedom and a significance level of α.
The computations lead to a value of the χ^2_c statistic inferior to the critical value $\chi^2_{0,01} = 6.635$, so that the H_0 hypothesis is accepted with a probability of 99%.

The three applied tests (Kolmogorov-Smirnov, Anderson-Darling and Pearson-Fisher) confirm with a high confidence degree the log-logistic distribution, by parameters:
$\alpha = 1.6112$
$\beta = 1.9994$
$\gamma = 0$
The Probability Density Function (pdf) for the estimated values of the parameters is presented in Figure 2, the Cumulative Distribution Function (cdf) in Figure 3, and hazard function in Figure 4.
Table 2 presents the values of the main indicators of the log-logistic distribution for a number of x = 0, …, 10 events.

Table 2 – The Values for pdf, CDF, h(x) şi S(x)

Statistic Functions	Values computed for **x** (earthquakes) equal to:									
	1	2	3	4	5	6	7	8	9	10
pdf- probability density function	0.3033	0.2077	0.1238	0.0757	0.0488	0.0333	0.0234	0.0171	0.0129	0.01000
CDF - cumulative distribution function	0.2467	0.3193	0.5001	0.6579	0.7535	0.8545	0.8828	0.9033	0.9186	0.9304
h(x) - hazard function	0.3975	0.4116	0.4029	0.3533	0.3035	0.2295	0.2032	0.1819	0.1645	0.1499
S(x) - distribution	0.7533	0.4998	0.3421	0.2465	0.1859	0.1455	0.1172	0.0967	0.8814	0.0696

Figure 2

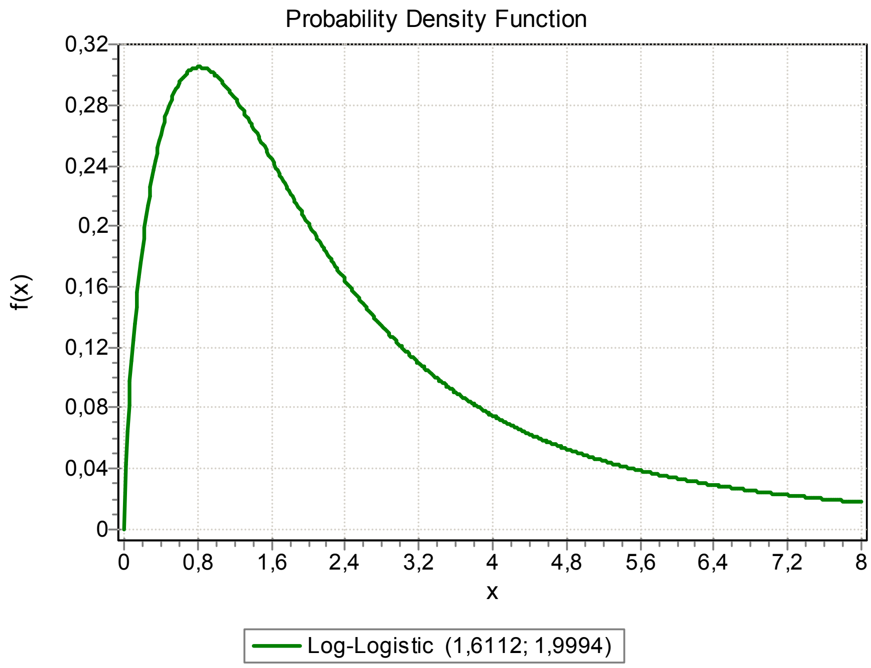


Figure 3

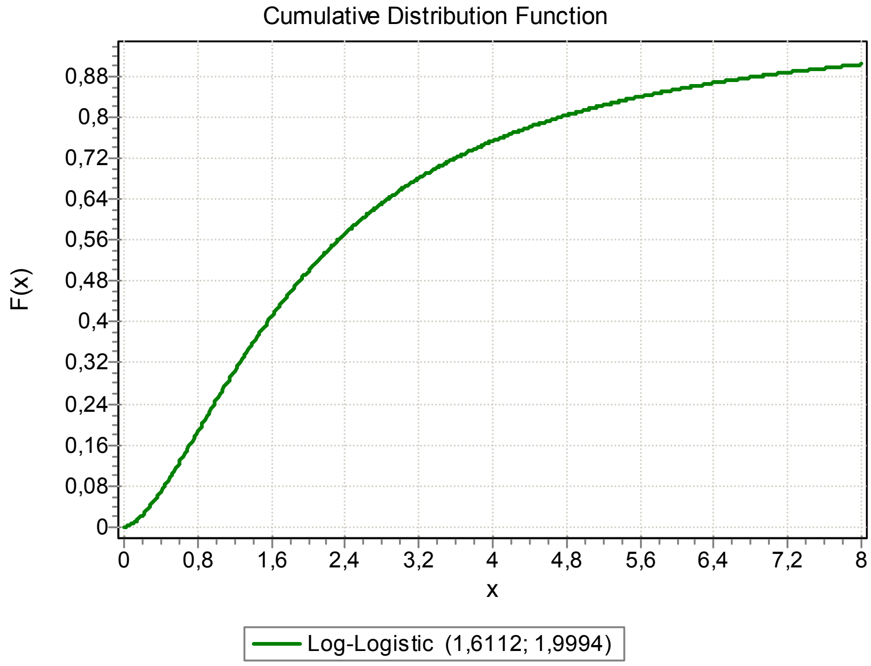
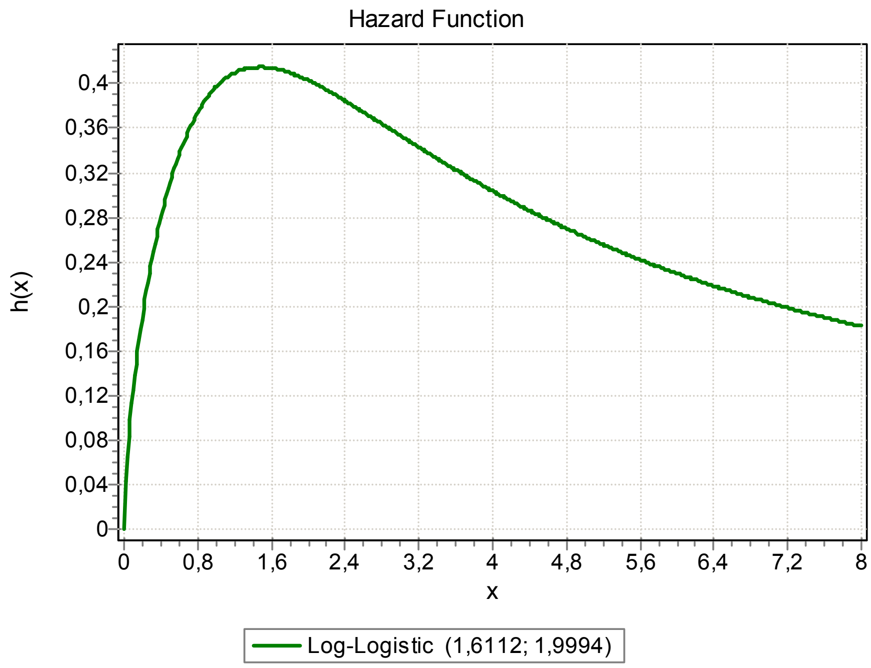


Figure 4



6. CONCLUSIONS

In the followings, through simulation operations for the values of the log-logistic distribution, we formulate various hypotheses on the occurrence of seismic events, for the confirmed statistic model.

Thus, if we limit, for a 50 year interval, the number of major seismic events to $x_1 = 1$ and $x_2 = 3$ respectively, we have:

$P(x < x_1) = 24{,}67\ \%$
$P(x > x_1) = 75{,}33\ \%$
$P(x_1 < x < x_2) = 41{,}112\ \%$
$P(x < x_2) = 62{,}79\ \%$
$P(x > x_2) = 34{,}22\ \%$

It is an optimistic variant that the chances for less than one major seismic event to occur in a 50 year interval are around 25%, and for more than 3 major seismic events, over 34%.

If we modify the limits to $x_1 = 8$ and $x_2 = 10$ major seismic events, then:

$P(x < x_1) = 90{,}33\ \%$
$P(x > x_1) = 9{,}67\ \%$
$P(x_1 < x < x_2) = 2{,}72\ \%$
$P(x < x_2) = 93\ \%$
$P(x > x_2) = 6{,}96\ \%$

So, there is a high probability that in Romania, less than 8 earthquakes will occur, and very slim chances that more than 10 earthquakes will occur. There is a probability of approximately 3% that in an interval of 50 years, between 8 and 10 events could occur.

Romania represents an unique case in the world, from a seismic point of view: earthquakes of over 7 degrees Richter in magnitude which originate from Vrancea affect approximately 50% of the territory and approximately 60% of the population, including Bucharest. Nonetheless, the earthquake in 1977 was not the most powerful. It was only the fourth in magnitude among the earthquakes in the last 200 years. In Romania, there were 6 earthquakes of over 7 degrees Richter in the last 200 years. More technical details on the area Vrancea can be found in Ivan (2007, 2011).

In the case of Romania, the warning period for an earthquake is 25-30 second, which is relatively short in comparison to Mexico City - 60 seconds. However, it is enough to interrupt dangerous activities: nuclear reactors, heavy water production, chemical industry, gases, electricity and water. For trains and subways, stopping the electrical power is enough to stop the carriages.

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