Statistical Approaches Regarding the Evolution of the Earthquakes in Romania

Gabriela OPAIT *

1. Introduction

This research reflects a statistical analysis of the trends concerning the magnitude of the earthquakes in Romania, respectively the depth of the earthquakes between the years 1940-2014. The purpose of the research reflects the possibility for to anticipate the values concerning the evolution in future of the magnitude for these earthquakes, respectively, the depth of the earthquakes by means of the forecasting methods. The statistical methods used are the „Coefficients of Variation Method”, the „Least Squares Method” applied for to calculate the parameters of the regression equation and the Forecasting Method through the „Least Squares Method”. The sections 2, respectively the section 3, present the methodology for to achieve the trends models for the magnitude of the earthquakes, respectively for the depth of the earthquakes, with the help of the „Least Squares Method”. The section 4 expresses the forecasting method through the „Least Squares Method”. The state of the art in this domain is represented by the research belongs to Carl Friederich Gauss, who created the „Least Squares Method” [1].

2. The modeling of the trend for the evolution regarding the magnitude of the earthquakes in Romania, between 1940-2014

In the period 1940-2014, we observe the next evolution concerning the magnitude of the earthquakes in Romania with the epicentre in Vrancea, according to the table no. 1:

Table no. 1  The evolution of the magnitudes concerning the earthquakes in Romania, between 1940-2014

<table>
<thead>
<tr>
<th>YEARS</th>
<th>THE MAGNITUDE OF THE EARTHQUAKES (RICHTER)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1940</td>
<td>7.7</td>
</tr>
<tr>
<td>1977</td>
<td>7.4</td>
</tr>
<tr>
<td>1986</td>
<td>7.1</td>
</tr>
<tr>
<td>1990</td>
<td>6.9</td>
</tr>
<tr>
<td>2004</td>
<td>6.0</td>
</tr>
<tr>
<td>2014</td>
<td>5.6</td>
</tr>
</tbody>
</table>

Source: „National Institute of Seismology from Romania”

We want to identify the trend model for the magnitudes of the earthquakes in Romania, in the period 1940-2014, using the table no.1.

- if we formulate the null hypothesis $H_0$: which mentions the assumption of the existence for the model of tendency of the factor $X = \text{the magnitude of the earthquakes in Romania}$, as being the function $x_i = a + b \cdot t_i$, then the parameters $a$ and $b$ of the adjusted linear function, can to be calculated by means of the next system [1]:

* Faculty of Economics and Business Administration, “Dunarea de Jos” University of Galati, Romania. E-mail address: Gabriela.opait@ugal.ro (G. Opait)
\[
S = \sum_{i=1}^{n} (x_i - \bar{x})^2 = \min \iff S = \sum_{i=1}^{n} (x_i - a - bt_i)^2 = \min
\]

\[
\frac{\partial S}{\partial a} = 0 \Rightarrow 2\sum_{i=1}^{n} (x_i - a - bt_i)(-1) = 0/(-1/2) \Rightarrow na + b\sum_{i=1}^{n} t_i = \sum_{i=1}^{n} x_i
\]

\[
\frac{\partial S}{\partial b} = 0 \Rightarrow 2\sum_{i=1}^{n} (x_i - a - bt_i)(-t_i) = 0/(-1/2) \Rightarrow a\sum_{i=1}^{n} t_i + b\sum_{i=1}^{n} t_i^2 = \sum_{i=1}^{n} x_i t_i
\]

Therefore,

\[
a = \frac{\sum_{i=1}^{n} x_i - \sum_{i=1}^{n} t_i \sum_{i=1}^{n} t_i^2}{n \sum_{i=1}^{n} t_i^2 - \left(\sum_{i=1}^{n} t_i\right)^2}
\]

\[
b = \frac{\sum_{i=1}^{n} x_i t_i - \sum_{i=1}^{n} t_i \sum_{i=1}^{n} x_i}{n \sum_{i=1}^{n} t_i^2 - \left(\sum_{i=1}^{n} t_i\right)^2}
\]

**Table no. 2** The estimate of the value for the variation coefficient in the case of the adjusted linear function, in the hypothesis concerning the linear evolution of the magnitude of the earthquakes in Romania, between the years 1940-2014

<table>
<thead>
<tr>
<th>YEARS</th>
<th>THE MAGNITUDE OF THE EARTHQUAKES IN ROMANIA (RICHTER) (x_i)</th>
<th>LINEAR TREND</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t_i</td>
<td>t_i^2</td>
</tr>
<tr>
<td>1940</td>
<td>7,7</td>
<td>-37</td>
</tr>
<tr>
<td>1977</td>
<td>7,4</td>
<td>0</td>
</tr>
<tr>
<td>1986</td>
<td>7,1</td>
<td>9</td>
</tr>
<tr>
<td>1990</td>
<td>6,9</td>
<td>13</td>
</tr>
<tr>
<td>2004</td>
<td>6,0</td>
<td>27</td>
</tr>
<tr>
<td>2014</td>
<td>5,6</td>
<td>37</td>
</tr>
<tr>
<td>TOTAL</td>
<td>40,7</td>
<td>49</td>
</tr>
</tbody>
</table>

If we calculate the statistical data for to adjust the linear function, we obtain for the parameters a and b the values:

\[
a = \frac{40,7}{237,9} = \frac{49}{3717} = \frac{151281,9 - 11657,1}{22302 - 2401} = 7,015969047
\]

\[
b = \frac{6}{49} = \frac{40,7}{237,9} = \frac{49}{3717} = \frac{1427,4 - 1994,3}{22302 - 2401} = -0,028486005
\]

Hence, the coefficient of variation for the adjusted linear function is:

\[
v = \left[ \frac{\sum_{i=m}^{n} |x_i - x_i^t|}{n} \cdot \frac{\sum_{i=m}^{n} x_i}{n} \right] \cdot 100 = \frac{\sum_{i=m}^{n} |x_i - x_i^t|}{\sum_{i=m}^{n} x_i} \cdot 100 = 1,95/40,7 \cdot 100 = 4,79%
\]

- in the situation of the alternative hypothesis $H_i$ which specifies the assumption of the existence for the model of tendency of the factor $X = \text{the magnitude of the earthquakes in Romania}$, as being the quadratic
function $x_i = a + b \cdot t_i + c t_i^2$, the parameters $a, b$ și $c$ of the adjusted quadratic function, can be calculated by means of the system [1]:

$$S = \sum_{i=1}^{n} (x_i - x_i^0)^2 = \min \iff S = \sum_{i=1}^{n} (x_i - a - bt_i - ct_i^2)^2 = \min$$

$$\begin{cases}
\frac{\partial S}{\partial a} = 0 \\
\frac{\partial S}{\partial b} = 0 \\
\frac{\partial S}{\partial c} = 0
\end{cases} \Rightarrow \begin{cases}
2\sum_{i=1}^{n} (x_i - a - bt_i - ct_i^2)(-1) = 0 / (-\frac{1}{2}) \\
2\sum_{i=1}^{n} (x_i - a - bt_i - ct_i^2)(-t_i) = 0 / (-\frac{1}{2}) \\
2\sum_{i=1}^{n} (x_i - a - bt_i - ct_i^2)(-t_i^2) = 0 / (-\frac{1}{2})
\end{cases}$$

Therefore,

$$\begin{cases}
n \cdot a + b \sum_{i=1}^{n} t_i + c \sum_{i=1}^{n} t_i^2 = \sum_{i=1}^{n} x_i \\
a \sum_{i=1}^{n} t_i + b \sum_{i=1}^{n} t_i^2 + c \sum_{i=1}^{n} t_i^3 = \sum_{i=1}^{n} x_i \cdot t_i \\
a \cdot \sum_{i=1}^{n} t_i^2 + b \sum_{i=1}^{n} t_i^3 + c \sum_{i=1}^{n} t_i^4 = \sum_{i=1}^{n} t_i^2 \cdot x_i
\end{cases}$$

Table no. 3 The estimates of the value for the variation coefficient in the case of the adjusted quadratic function, in the hypothesis concerning the parabolic evolution of the magnitude of the earthquakes in Romania, between the years 1940-2014

<table>
<thead>
<tr>
<th>YEARS</th>
<th>MAGNITUDE OF THE EARTHQUAKES IN ROMANIA (RICHTER)</th>
<th>PARABOLIC TREND</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$x_i$</td>
<td>$t_i$</td>
</tr>
<tr>
<td>1940</td>
<td>7,7</td>
<td>-37</td>
</tr>
<tr>
<td>1977</td>
<td>7,4</td>
<td>0</td>
</tr>
<tr>
<td>1986</td>
<td>7,1</td>
<td>9</td>
</tr>
<tr>
<td>1990</td>
<td>6,9</td>
<td>13</td>
</tr>
<tr>
<td>2004</td>
<td>6,0</td>
<td>27</td>
</tr>
<tr>
<td>2014</td>
<td>5,6</td>
<td>37</td>
</tr>
<tr>
<td>TOTAL</td>
<td>40,7</td>
<td>49</td>
</tr>
</tbody>
</table>

If we calculate the statistical data for to adjust the quadratic function, we obtain for the parameters $a$, $b$ and $c$ the next values:

$$\begin{cases}
6 \cdot a + 49 \cdot b + 3717 \cdot c = 40,7 \\
49 \cdot a + 3717 \cdot b + 22609 \cdot c = 237,9 \\
3717 \cdot a + 22609 \cdot b + 4314885 \cdot c = 24322,9
\end{cases} \Rightarrow a = 7,371877263, b = -0,029787701, c = -0,000557349$$

So, the coefficient of variation for the adjusted quadratic function has the value:

$$v_H = \left[ \frac{\sum_{i=m}^{n} |x_i - x_i^H|}{n} \cdot \frac{\sum_{i=m}^{n} x_i}{n} \right] \cdot 100 = \left[ \frac{\sum_{i=m}^{n} |x_i - x_i^H|}{\sum_{i=m}^{n} x_i} \right] \cdot 100 = 0,34 \cdot 40,7 \cdot 100 = 0,84\%$$

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- in the case of the alternative hypothesis $H_2$ : which describes the supposition the assumption of the existence for the model of tendency of the factor $X = \text{the magnitude of the earthquakes in Romania}$, as being the exponential function $x_i = ab^t$, then the parameters $a$ and $b$ of the adjusted exponential function, can to be calculated by means of the next system [1]:

$$S = \sum_{i=1}^n (\lg x_i - \lg x_i)^2 = \min \iff S = \sum_{i=1}^n (\lg x_i - \lg a - t_i \lg b)^2 = \min$$

\[
\begin{align*}
\frac{\partial S}{\partial \lg a} = 0 & \Rightarrow 2 \sum_{i=1}^n (\lg x_i - \lg a - t_i \lg b)(-1) = 0 / \frac{1}{2} \\
\frac{\partial S}{\partial \lg b} = 0 & \Rightarrow 2 \sum_{i=1}^n (\lg x_i - \lg a - t_i \lg b)(-t_i) = 0 / \frac{1}{2}
\end{align*}
\]

\[
\begin{align*}
& n \cdot \lg a + \lg b \cdot \sum_{i=1}^n t_i = \sum_{i=1}^n \lg x_i \\
& \lg a \sum_{i=1}^n t_i + \lg b \cdot \sum_{i=1}^n t_i^2 = \sum_{i=1}^n t_i \cdot \lg x_i
\end{align*}
\]

Thus,

$$\lg a = \frac{\sum_{i=1}^n \lg x_i - \sum_{i=1}^n t_i \lg x_i}{n \sum_{i=1}^n t_i - \left(\sum_{i=1}^n t_i\right)^2}$$

and

$$\lg b = \frac{n \sum_{i=1}^n \lg x_i - \sum_{i=1}^n t_i \lg x_i}{n \sum_{i=1}^n t_i^2 - \left(\sum_{i=1}^n t_i\right)^2}$$

<table>
<thead>
<tr>
<th>YEARS</th>
<th>THE MAGNITUDE OF THE EARTHQUAKES IN ROMANIA (RICHTER)</th>
<th>EXPONENTIAL TREND</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$t_i$</td>
<td>$\lg x_i$</td>
</tr>
<tr>
<td>1940</td>
<td>7,7</td>
<td>-37</td>
</tr>
<tr>
<td>1977</td>
<td>7,4</td>
<td>0</td>
</tr>
<tr>
<td>1986</td>
<td>7,1</td>
<td>9</td>
</tr>
<tr>
<td>1990</td>
<td>6,9</td>
<td>13</td>
</tr>
<tr>
<td>2004</td>
<td>6,0</td>
<td>27</td>
</tr>
<tr>
<td>2014</td>
<td>5,6</td>
<td>37</td>
</tr>
<tr>
<td>TOTAL</td>
<td>40,7</td>
<td>49</td>
</tr>
</tbody>
</table>
Consequently, if we calculate the statistical data for to adjust the exponential function, we obtain for the parameters $a$ and $b$ the values:

$$\log a = \frac{4.972169159}{34.45924725} \times 6 \times 49, \quad 3717 = \frac{18481.55276 - 1688.503115}{22302 - 2401} = 0.843829438$$

$$\log b = \frac{4.972169159}{34.45924725} \times 6 \times 49, \quad 3717 = \frac{206.7554835 - 243.64362888}{22302 - 2401} = -0.001853213$$

Accordingly, the coefficient of variation for the adjusted exponential function has the next value:

$$v_{exp} = \frac{\sum_{i=m}^{n} |x_i - x_{i exp}|}{n} \cdot \frac{\sum_{i=m}^{n} x_i}{n} \cdot \frac{\sum_{i=m}^{n} x_i}{\sum_{i=m}^{n} x_i} \cdot 100 = \frac{2.15}{40.7} \cdot 100 = 5.28\%$$

We apply the coefficients of variation method as criterion of selection for the best model of trend. We notice that:

$$v_H = 0.84\% < v_J = 4.79\% < v_{exp} = 5.28\%$$

So, the path reflected by X factor, which represents the magnitude of the earthquakes in Romania, between 1940-2014, is a **parabolic trend** of the shape $x_i = a + b \cdot t_i + c t_i^2$, with other words it confirms the hypothesis $H_1$.

**Figure 1. The trend model of the values for the magnitudes of the earthquakes in Romania, in the period 1940-2014**

We observe that, the cloud of points which reflects the values of the magnitudes concerning the earthquakes in Romania, between 1940-2014, it carrying around a parabolic model of trend, according to the type no.1.

3. **The modeling of the trend for the evolution concerning the depth of the earthquakes in Romania, between 1940-2014**

Also, we want to identify the trend model for the depth of the earthquakes in Romania, in the period 1940-2014, using the table no.1.
- if we formulate the null hypothesis \( H_0 \); which mentions the assumption of the existence for the model of tendency of the factor \( Y = \) the depth of the earthquakes in Romania, as being the function \( y_i = a + b \cdot t_i \), then the parameters \( a \) and \( b \) of the adjusted linear function, can to be calculated by means of the next system [1]:

\[
S = \sum_{i=1}^{n} (y_i - y_{\bar{y}})^2 = \min \iff S = \sum_{i=1}^{n} (y_i - a - bt_i)^2 = \min
\]

\[
\begin{align*}
\frac{\partial S}{\partial a} &= 0 \\
\frac{\partial S}{\partial b} &= 0
\end{align*}
\]

\[
\Rightarrow \begin{cases} 
2\sum_{i=1}^{n} (y_i - a - bt_i) = 0 \iff na + b\sum_{i=1}^{n} t_i = \sum_{i=1}^{n} y_i \\
2\sum_{i=1}^{n} (y_i - a - bt_i) = 0 \iff a\sum_{i=1}^{n} t_i + b\sum_{i=1}^{n} t_i^2 = \sum_{i=1}^{n} y_i t_i
\end{cases}
\]

Therefore,

\[
\begin{align*}
a &= \frac{\sum_{i=1}^{n} y_i - \sum_{i=1}^{n} t_i}{\sum_{i=1}^{n} t_i - \left(\sum_{i=1}^{n} t_i \right)^2} \\
b &= \frac{n\sum_{i=1}^{n} y_i t_i - \sum_{i=1}^{n} y_i \sum_{i=1}^{n} t_i}{n\sum_{i=1}^{n} t_i^2 - \left(\sum_{i=1}^{n} t_i \right)^2}
\end{align*}
\]

Table no. 5 The estimate of the value for the variation coefficient in the case of the adjusted linear function, in the hypothesis concerning the linear evolution for the depth of the earthquakes in Romania, between the years 1940-2014

<table>
<thead>
<tr>
<th>YEARS</th>
<th>THE DEPTH OF THE EARTHQUAKES IN ROMANIA (KM)</th>
<th>A. LINEAR TREND</th>
<th>B.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( y_i )</td>
<td>( t_i )</td>
<td>( t_i^2 )</td>
</tr>
<tr>
<td>1940</td>
<td>150,0</td>
<td>-37</td>
<td>1369</td>
</tr>
<tr>
<td>1977</td>
<td>94,0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1986</td>
<td>131,4</td>
<td>9</td>
<td>81</td>
</tr>
<tr>
<td>1990</td>
<td>90,9</td>
<td>13</td>
<td>169</td>
</tr>
<tr>
<td>2004</td>
<td>98,6</td>
<td>27</td>
<td>729</td>
</tr>
<tr>
<td>2014</td>
<td>39,0</td>
<td>37</td>
<td>1369</td>
</tr>
<tr>
<td>TOTAL</td>
<td>603,9</td>
<td>49</td>
<td>3717</td>
</tr>
</tbody>
</table>

If we calculate the statistical data for to adjust the linear function, we obtain for the parameters \( a \) and \( b \) the values:

\[
a = \frac{603,9 \cdot 49}{919,5 \cdot 3717} = \frac{2244696,3 - 45055,5}{22302 - 2401} = 110,5291593
\]

\[
b = \frac{6 \cdot 603,9}{49 \cdot 919,5} = \frac{5517 - 29591,1}{22302 - 2401} = -1,20969298
\]

Hence, the coefficient of variation for the adjusted linear function is:
\[
v_i = \left( \frac{\sum_{i=1}^{n} |y_i - y'_i|}{n} : \frac{\sum_{i=1}^{n} y_i}{n} \right) \cdot 100 = \frac{\sum_{i=1}^{n} |y_i - y'_i|}{\sum_{i=1}^{n} y_i} \cdot 100 = \frac{105,28}{603,9} \cdot 100 = 17,43\%
\]

- in the situation of the alternative hypothesis \( H_1 \): which specifies the assumption of the existence for the model of tendency of the factor \( Y = \) the depth of the earthquakes in Romania, as being the quadratic function \( y_i = a + b \cdot t_i + c t_i^2 \), the parameters \( a, b \) și \( c \) of the adjusted quadratic function, can to be calculated by means of the system [1]:

\[
S = \sum_{i=1}^{n} (y_i - y_a)^2 = \text{min} \Leftrightarrow S = \sum_{i=1}^{n} (y_i - a - b t_i - c t_i^2)^2 = \text{min}
\]

\[
\begin{align*}
\frac{\partial S}{\partial a} &= 0 \\
\frac{\partial S}{\partial b} &= 0 \\
\frac{\partial S}{\partial c} &= 0
\end{align*}
\Rightarrow
\begin{align*}
2 \sum_{i=1}^{n} (y_i - a - b t_i - c t_i^2)(-1) &= 0 / (-\frac{1}{2}) \\
2 \sum_{i=1}^{n} (y_i - a - b t_i - c t_i^2)(-t_i) &= 0 / (-\frac{1}{2})
\end{align*}
\]

Therefore,

\[
\begin{align*}
n \cdot a + b \sum_{i=1}^{n} t_i + c \sum_{i=1}^{n} t_i^2 &= \sum_{i=1}^{n} y_i \\
 a \sum_{i=1}^{n} t_i + b \sum_{i=1}^{n} t_i^2 + c \sum_{i=1}^{n} t_i^3 &= \sum_{i=1}^{n} t_i \cdot y_i \\
 a \sum_{i=1}^{n} t_i^2 + b \sum_{i=1}^{n} t_i^3 + c \sum_{i=1}^{n} t_i^4 &= \sum_{i=1}^{n} t_i^2 \cdot y_i
\end{align*}
\]

Table no. 6 The estimates of the value for the variation coefficient in the case of the adjusted quadratic function, in the hypothesis concerning the parabolic evolution for the depth of the earthquakes in Romania, between the years 1940-2014

<table>
<thead>
<tr>
<th>YEARS</th>
<th>THE DEPTH OF THE EARTHQUAKES IN ROMANIA (KM)</th>
<th>PARABOLIC TREND</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( (y_i) )</td>
<td>( t_i )</td>
</tr>
<tr>
<td>1940</td>
<td>150,0</td>
<td>-37</td>
</tr>
<tr>
<td>1977</td>
<td>94,0</td>
<td>0</td>
</tr>
<tr>
<td>1986</td>
<td>131,4</td>
<td>9</td>
</tr>
<tr>
<td>1990</td>
<td>90,9</td>
<td>13</td>
</tr>
<tr>
<td>2004</td>
<td>98,6</td>
<td>27</td>
</tr>
<tr>
<td>2014</td>
<td>39,0</td>
<td>37</td>
</tr>
<tr>
<td>TOTAL</td>
<td>603,9</td>
<td>49</td>
</tr>
</tbody>
</table>

If we calculate the statistical data for to adjust the quadratic function, we obtain for the parameters \( a, b \) and \( c \) the next values:

\[
\begin{align*}
6 \cdot a + 49 \cdot b + 3717 \cdot c &= 603,9 \\
49 \cdot a + 3717 \cdot b + 22609 \cdot c &= 919,5 \\
3717 \cdot a + 22609 \cdot b + 4314885 \cdot c &= 356625,9
\end{align*}
\Rightarrow
\begin{align*}
a &= 119,1308559 \\
b &= -1,241152726 \\
c &= -0,013470178
\end{align*}

49
So, the coefficient of variation for the adjusted quadratic function has the value:

\[
v_{ll} = \left[ \frac{\sum_{i=1}^{n} y_i^2 - y_i^\prime_{\hat{H}}^2}{n} : \frac{\sum_{i=1}^{n} y_i}{n} \right] \cdot 100 = \frac{\sum_{i=1}^{n} y_i^2 - y_i^\prime_{\hat{H}}^2}{\sum_{i=1}^{n} y_i} \cdot 100 = \frac{101,44}{603,9} \cdot 100 = 16,80\%
\]

- in the case of the alternative hypothesis \( H_2 \): which describes the supposition the assumption of the existence for the model of tendency of the factor \( Y = \) the depth of the earthquakes in Romania, as being the exponential function \( y_i = a b^t \), then the parameters \( a \) and \( b \) of the adjusted exponential function, can to be calculated by means of the next system [1]:

\[
S = \sum_{i=1}^{n} (\lg y_i - \lg y_i^\prime)^2 = \min \iff S = \sum_{i=1}^{n} (\lg y_i - \lg a - t_i \lg b)^2 = \min
\]

\[
\begin{align*}
\frac{\partial S}{\partial \lg a} &= 0 \quad \Rightarrow \quad \frac{2\sum_{i=1}^{n} (\lg y_i - \lg a - t_i \lg b)(-1)}{2} = 0 / (-\frac{1}{2}) \\
\frac{\partial S}{\partial \lg b} &= 0 \quad \Rightarrow \quad \frac{2\sum_{i=1}^{n} (\lg y_i - \lg a - t_i \lg b)(-t_i)}{2} = 0 / (-\frac{1}{2})
\end{align*}
\]

\[
\begin{align*}
\left\{ \begin{array}{l}
n \cdot \lg a + \lg b \cdot \sum_{i=1}^{n} t_i = \sum_{i=1}^{n} \lg y_i \\
\lg a \sum_{i=1}^{n} t_i + \lg b \cdot \sum_{i=1}^{n} t_i^2 = \sum_{i=1}^{n} t_i \cdot \lg y_i
\end{array} \right.
\end{align*}
\]

Thus,

\[
\lg a = \frac{\sum_{i=1}^{n} \lg y_i \sum_{i=1}^{n} t_i - \sum_{i=1}^{n} \sum_{i=1}^{n} \lg y_i \sum_{i=1}^{n} t_i}{n \sum_{i=1}^{n} t_i - \left( \sum_{i=1}^{n} t_i \right)^2}
\]

and

\[
\lg b = \frac{\sum_{i=1}^{n} t_i \sum_{i=1}^{n} \lg y_i - n \cdot \sum_{i=1}^{n} t_i \sum_{i=1}^{n} \lg y_i \sum_{i=1}^{n} t_i}{n \sum_{i=1}^{n} t_i^2 - \left( \sum_{i=1}^{n} t_i \right)^2}
\]
Table no. 7 The estimate of the value for the variation coefficient in the case of the adjusted exponential function, in the hypothesis concerning the exponential evolution for the depth of the earthquakes in Romania, between 1940-2014

| YEARS | THE DEPTH OF THE EARTHQUAKES IN ROMANIA (KM) (yi) | EXPONENTIAL TREND | | | | |
|-------|--------------------------------------------------|-------------------|---|---|---|---|---|
| 1940  | 150,0                                            | ti                 | lg yi | t_i lg y_i | lg y_i = = lg a + t_i lg b  | y_i = ab^{t_i} | y_i - y_i | |
| 1977  | 94,0                                             | 0                 | 1,973127854 | 0 | 2,017161169 | 104,0306157 | 10,03 |
| 1986  | 131,4                                            | 9                 | 2,118595365 | 19,06735829 | 1,963593331 | 91,95880754 | 39,44 |
| 1990  | 90,9                                             | 13                | 1,958563883 | 25,46133048 | 1,939785403 | 87,05333289 | 3,85 |
| 2004  | 98,6                                             | 27                | 1,993876915 | 53,8467670  | 1,856457655 | 71,85510941 | 26,74 |
| 2014  | 39,0                                             | 37                | 1,591064607 | 58,86939046 | 1,796937835 | 62,65241775 | 23,65 |
| TOTAL | 603,9                                            | 49                | 11,81131988 | 76,71737934 | 126,45 |

Consequently, if we calculate the statistical data for to adjust the exponential function, we obtain for the parameters \( a \) and \( b \) the values:

\[
\begin{align*}
\lg a &= \frac{11,81131988}{76,71737934} = \frac{43902,67601 - 3759,151588}{22302 - 2401} = 2,017161169 \\
\lg b &= \frac{11,81131988}{76,71737934} = \frac{460,304276 - 578,7546741}{22302 - 2401} = -0,005951982
\end{align*}
\]

Accordingly, the coefficient of variation for the adjusted exponential function has the next value:

\[
\nu_{\text{exp}} = \left[ \frac{\sum_{i=1}^{n} y_i - y_i^{\text{exp}}}{n} \cdot \frac{\sum_{i=1}^{n} y_i}{n} \right] \cdot 100 = \left( \frac{\sum_{i=1}^{n} y_i - y_i^{\text{exp}}}{\sum_{i=1}^{n} y_i} \right) \cdot 100 = \frac{126,45}{603,9} \cdot 100 = 20,94\%
\]

We apply the coefficients of variation method as criterion of selection for the best model of trend. We notice that:

\[
\nu_{\text{Hz}} = 16,80\% < \nu_j = 17,43\% < \nu_{\text{exp}} = 20,94\%
\]

So, the path reflected by \( Y \) factor, which represents the depth of the earthquakes in Romania, between 1940-2014, is a **parabolic trend** of the shape \( y_i = a + b \cdot t_i + c t_i^2 \), with other words it confirms the hypothesis \( H_1 \).
The parabolic trend regarding the depth of the earthquakes in Romania, in the period 1940-2014

We observe that the cloud of points which reflects the values for the depth of the earthquakes from Romania, between 1940-2014, carries around a parabolic model of trend, according to the type no. 2.

4. The forecasting method through the „Least Squares Method”

We know that the evolution of the magnitudes concerning the earthquakes in Romania, between 1940-2014, reflects a parabolic trend of the shape \( x_i = a + b \cdot t_i + c t_i^2 \). So, in 2015, the magnitude concerning a possible earthquake will be:

\[
MAGNITUDE_{earthquake}^{2015} = 7.371877263 + (-0.029787701) \cdot 50 + (-0.000557349) \cdot 50^2 = 4.5 \text{ degrees}
\]

Also, the trend of the values regarding the depth of the earthquakes in Romania, in the period 1940-2014, is a parabolic trend of the shape \( y_i = a + b \cdot t_i + c t_i^2 \). Thus, in 2015, the depth concerning a possible earthquake will be:

\[
DEPTH_{earthquake}^{2015} = 119.1308559 + (-1.241152726) \cdot 50 + (-0.013470178) \cdot 50^2 = 23.40 \text{ km}
\]

4. Conclusions

We can to synthesize that in future, the evolutions regarding the magnitudes of the earthquakes in Romania, with the epicentre in Vrancea, have an unexpected character, while the fortuitous factor plays the principal role. According to the National Institute of Seismology from Bucharest, because the intensity of the earthquakes grew in the last time in Vrancea, we can to have between 15-20 of earthquakes in each month in 2015.

References
5. www.emsc-csem.org