PROCESSING AND INTERPRETATION OF STATISTICAL DATA REGARDING THE OCCURRENCE OF EARTHQUAKES

Cristina Coculescu [1]*
Mironela Pirnau [2]
Mihai Alexandru Botezatu [3]

ABSTRACT

This work aims the analysis of the statistical data for a disaster situation. The statistical research of this paper is based on the devastating incident in Rieti for which we used the statistical observation, the primary data processing and we obtained the statistical indicators, and we analysed and interpreted the results of the collected data processing. The used statistical indicators have the role to allow the quantification of certain mass phenomena. In the present times, the numerical modeling represents the only tool to perceive the evolution of the seismic activity in time and space. Even if the process of generating earthquakes is influenced by a complex of certain physical and chemical processes, there is no system to simulate and analyse the seismic process in its complex form, anywhere in the world.

KEYWORDS: *statistical methods, numerical simulation, data collecting, disaster situation, earthquak.*

1. INTRODUCTION

Statistics arose in response to the need for knowing the numerical reality of the phenomena that happen around us and aims to obtain numerically expressed statistical data with respect to statistical collectivities [1-2].

Statistics is a science which makes use of research methods for collecting, storing, processing / modelling and interpreting the obtained data. The purpose of statistics is to extract information from collected data in order to better understand the phenomenon that is reflected by these data. Basically, statistics is not limited to collecting, systematizing, modelling and interpreting the statistical data, in fact, its main purpose is to find the causes of the phenomenon and to formulate, based on these, the predictions that could support the facts and value based decision making.

Statistical methods are represented by a set of methodological and technical principles used in investigating the mass phenomena [3-6]. Statistical methods are meant to be at the basis of real phenomena modelling based on stored value information.

[1*] corresponding author, Associate Professor, PhD., Romanian-American University, Bucharest, coculescu.cristina@profesor.rau.ro

[2] Associate Professor, PhD., Titu Maiorescu University, Bucharest, mironela.pirnau@utm.ro

[3] Lecturer PhD, Faculty of Computer Science for Business Management, Romanian - American University, Bucharest, botezatu.mihai.alexandru@profesor.rau.ro

In any statistical research it is used a set of basic concepts, closely related to the field covered by the studied phenomenon or process [7-10]. In this paper, we took into account the following concepts: statistical collectivity (population), sample; statistical unit / observation unit; statistical feature; observation; frequency; probability; parameter; estimator; precision; accuracy; displacement; statistical indicator [11-12].

2. PRELIMINARY INFORMATION ON STATISTICS AND EARTHQUAKES

In practice, the way in which statistical data can be obtained within a research study depends on the knowledge that we follow, namely what we really want to know. For this research, we have followed the stages shown in Figure 1.
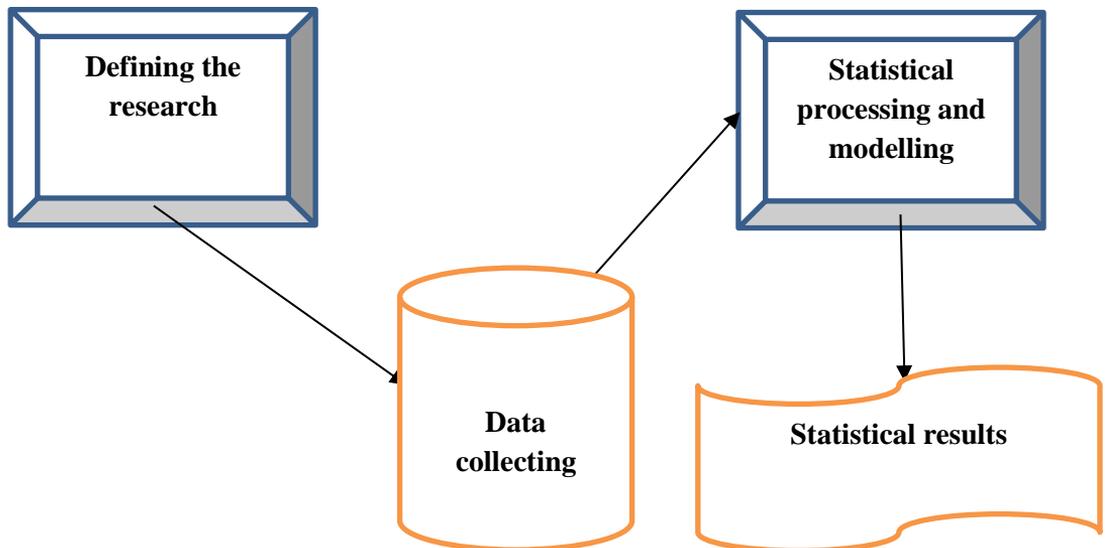

Figure 1. Statistical research stages

There are countless online publications (websites) that provide almost real-time seismicity situation of a particular region or worldwide [13-15]. The information that these websites make available can be analysed and interpreted using statistical indicators. Among this variety of websites, we mention as follows:

- http://cnt.rm.ingv.it/
- http://www.emsc-csem.org/
- http://ds.iris.edu/seismon/eventlist/index.phtml
- http://earthquake.usgs.gov/
- http://www.world-earthquakes.com/index.php
- http://www.deprem.gov.tr/
- http://www.gein.noa.gr/en/seismicity/earthquake-catalogs
- http://www.snas.ro
- http://www.infp.ro/

For this paper, we extracted information from **http://cnt.rm.ingv.it/,** following the devastating earthquake in Rieti. Since the distribution in space and time of the seismicity plays a crucial role for numerical simulation we analysed the data extracted for the following periods of time:

- 2016-05-28 01:57:39÷**2016-08-24 01:36:31/03.36:31 local time** (90 days)
- **2016-08-24 01:36:32** ÷ 2016-09-19 15:36:47 (26 days)

First of all we carried out a coherent database of the events which occurred on the occasion of the earthquake in Rieti so that, by numerical simulations, we could study the frequency and intensity of the aftershocks in the areas subject to the analysis herein. The theoretical basis of this paper relies on numerous research studies in the field of data analysis in case of disaster and also software tools models for the analysis of the data published in social media in case of an earthquake [16-27]. The analysis started from the real situation that took place in Rieti, and aimed to the statistical research and interpretation of the frequency of earthquakes occurrence in regions such as *Rieti, Perugia, L'Aquila, Ascoli Piceno, Macerata* as well as in other cities according to magnitude and depth criteria.

3. STATISTICAL PROCESSING AND MODELLING OF THE DATA REGARDING THE EARTHQUAKE IN RIETI

Since **statistical grouping** is a method of data systematizing by which the amount of recorded data compresses depending on one or more features, we analysed the collected data both according to magnitude and earthquakes depth and we also combined these essential earthquakes features. For the analysed periods of time, we calculated the number of earthquakes that occurred in Rieti, Perugia, L'Aquila, Ascoli Piceno and Macerata according to two grouping criteria: magnitude and earthquakes depth. In Table 1 we calculated the number of earthquakes according to their magnitude between 2016-05-28 01:57:39 39 ÷ **2016-08-24 01:36:31** and in Table 2 we calculated the number of earthquakes in the aftermath of the devastating earthquake in Rieti (**2016-08-24 01:36:32** ÷ 2016-09-19 15:36:47), also according to magnitude.

Table 1. Number of earthquakes between 2016-05-28 ÷ 2016-08-24 01:36:31

Magnitude	Rieti	Perugia	L'Aquila	Ascoli Piceno	Macerata	Other cities
[2-3)	4	14	4	3	5	293
[3-4)	0	0	1	0	0	44
[4 - 6]	0	0	0	0	0	7
>=6	**0**	**0**	**0**	**0**	**0**	23
Total	4	14	5	3	5	367

Table 2. Number of earthquakes between 2016-08-24 01:36:32 ÷ 2016-09-19

Magnitude	Rieti	Perugia	L'Aquila	Ascoli Piceno	Macerata	Total
[2-3)	677	421	39	384	145	1666
[3-4)	75	57	6	38	13	189
[4-6)	7	5	0	2	1	15
>6	**1**	**0**	**0**	**0**	**0**	1
Total	760	483	45	424	159	1871

A graphical representation of the large number of earthquakes that occurred after 08/24/2016 in Rieti, Perugia, L'Aquila, Ascoli Piceno and Macerata grouped according to magnitude was carried out in Figure 2 based on the data grouped in Table 2.
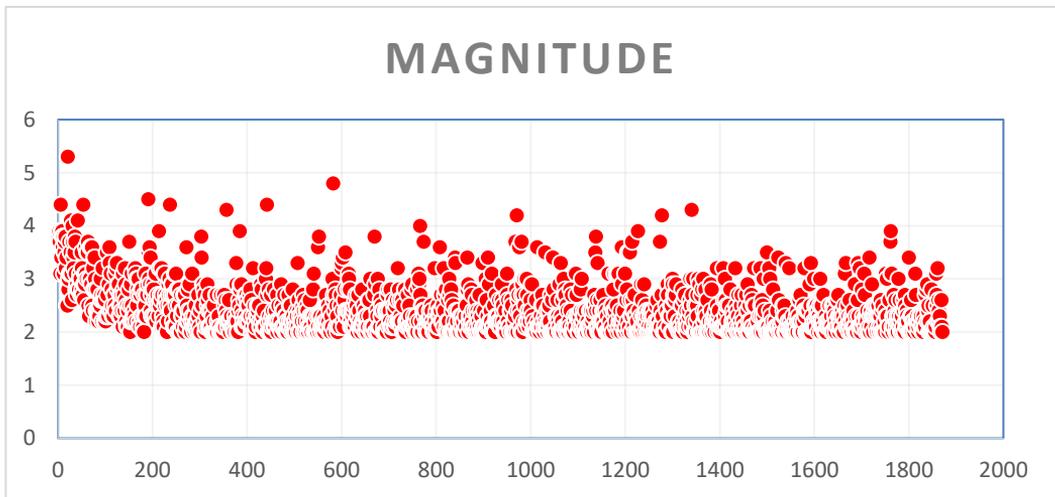

Figure 2. Frequency of earthquakes according to magnitude after 24.08.2016

If we only analyse the number of earthquakes in Rieti we notice that during the analysed period of time no earthquake has exceeded 5 degrees, as shown in Figure 3. We can easily notice that in the following 26 days after the devastating earthquake that took place in Rieti, the region faced 760 earthquakes compared to those 4 that occurred 90 days before the earthquake. Since it is agreed that there are more active areas for earthquakes production based on depth, we grouped the analysis of the earthquakes which occurred in those 5 regions in Italy on 5 categories of depth, as shown in Tables 3 and 4.

If we analyse the extracted data for the same periods depending on the depth at which the earthquakes occurred, we obtain the results in Table 3 for the information gathered during 2016-05-28 ÷ 2016-08-24 01:36:31and Table 4 for the information gathered during **2016-08-24 01:36:32** ÷ 2016-09-19. Basically, the earthquakes that occurred 118 days before the catastrophe in Rieti were at depths of 9, 11, 12 and 13 km, and, in this period, only 9 earthquakes occurred under the depth of 5 km worldwide.
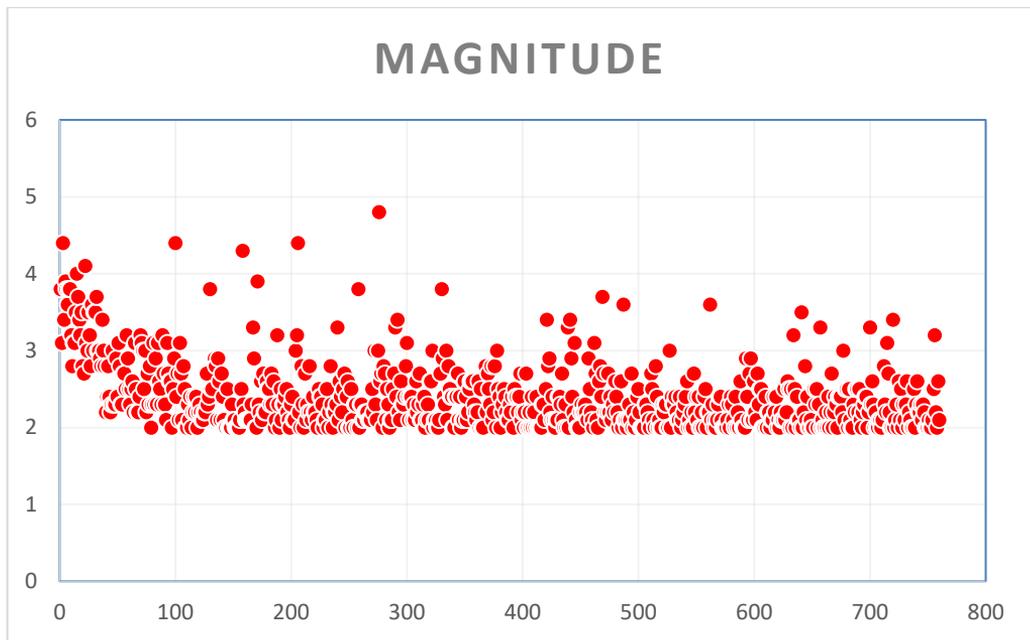
Figure 3. Frequency of earthquakes in Rieti after 24.08.2016

Table 3. Number of earthquakes occurred before 08.24.2016 according to depth

Depth	Rieti	Perugia	L'Aquila	Ascoli Piceno	Macerata	Other cities
<5km	0	0	0	0	0	**9**
[5-10]	**1**	6	0	0	0	83
[10-15]	**3**	6	5	1	3	91
[15-20]	0	1	0	0	0	26
[20-30]	0	0	0	2	2	63
>30	0	1	0	0	0	95
Total	4	14	5	3	5	367

Table 4. Number of earthquakes according to depth that occurred after 24.08.2016

Depth	Rieti	Perugia	L'Aquila	Ascoli Piceno	Macerata	Total
<5km	**10**	**5**	**0**	**2**	**1**	**18**
[5-10)	209	165	4	227	102	707
[10-15)	519	306	36	173	52	1086
[15-20)	22	7	5	20	2	56
>=20	0	0	0	2	2	4
Total	760	483	45	424	159	1871

According to analysed data, after the earthquake which took place in Rieti, until 2016-09-19, in the 5 analysed provinces, 18 earthquakes occurred at a depth less than 5 km, but they did not exceed 3.8 magnitude, according to Table 5.

Table 5. Number of earthquakes grouped according to time, place, magnitude and depth.

Date and Time (UTC)	Province/Area	Magnitude	Depth earthquake
2016-08-24 01:40:45	Ascoli Piceno	3.8	4
2016-08-24 02:30:49	Perugia	3.4	4
2016-08-24 02:55:39	Rieti	3.5	1
2016-08-24 03:13:10	Rieti	3.2	3
2016-08-24 03:45:42	Perugia	2.8	4
2016-08-24 06:19:42	Perugia	2.6	4
2016-08-24 06:45:09	Perugia	2.6	4
2016-08-24 07:25:02	Rieti	3.1	4
2016-08-24 07:52:17	Rieti	3.2	3
2016-08-24 08:52:09	Ascoli Piceno	2.1	4
2016-08-24 10:00:40	Rieti	2.4	4
2016-08-24 11:05:42	Rieti	2.8	2
2016-08-24 22:02:02	Rieti	2.2	1
2016-08-25 02:08:01	Rieti	2	4
2016-08-25 21:56:04	Perugia	2.1	4
2016-08-28 15:53:32	Rieti	2.4	4
2016-09-06 00:36:37	Macerata	2	4
Calculations	**STDEV**	**0.56814973**	**1.064121**
	Average	2.71764706	3.411765
	Min	**2**	**1**
	Max	**3.8**	**4**

For the earthquakes that occurred after 08.24.2016 in Italy, at a depth of less than 5 Km we notice that the magnitude average is 2.7 and STDEV is 0.56. If we also take into account, the devastating earthquake in Rieti then the average is 2.9 and STDEV is 0.94 (an increase of approximately 0.4). Both an analysis and a discussion can be brought out for the graphical representation of the analyzed earthquakes as well, depending on depth and magnitude, as shown in Figure 4 (see also table 4 row 1). However, during the analyzed period of time [21-26], following the earthquake in Rieti, 15 earthquakes of magnitude between **4 and 5.3** occurred but none of them occurred under 5 Km, according to data collected in Table 6.
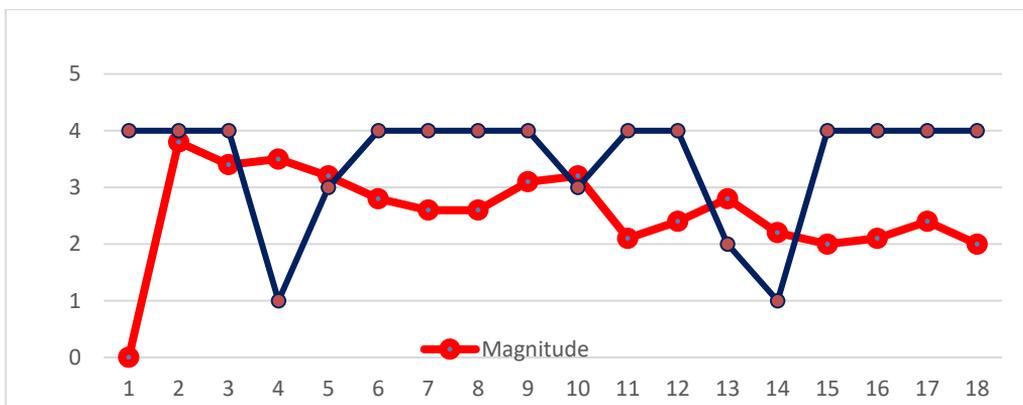
Figure 4. Earthquakes occurrence according to depth and magnitude after the earthquake in Rieti

Table 6. Magnitude between **4 and 5.3**

| Date and Time (UTC)	Province/ Area	Magnitude	Depth Earthquake
2016-08-24 01:56:00	Rieti	4.40	5
2016-08-24 02:33:29	Perugia	5.30	9
2016-08-24 02:59:35	Perugia	4.10	9
2016-08-24 03:08:10	Rieti	4.00	15
2016-08-24 03:40:11	Rieti	4.10	11
2016-08-24 04:06:50	Perugia	4.40	8
2016-08-24 11:50:30	Perugia	4.50	8
2016-08-24 17:46:09	Rieti	4.40	10
2016-08-25 03:17:16	Rieti	4.30	10
2016-08-25 12:36:05	Rieti	4.40	10
2016-08-26 04:28:25	Rieti	4.80	11
2016-08-27 02:50:59	Ascoli Piceno	4.00	8
2016-08-28 15:55:35	Ascoli Piceno	4.20	9
2016-09-03 01:34:12	Perugia	4.20	11
2016-09-03 10:18:51	Macerata	4.30	9
statistical calculations	**STDEV**	**0.333381**	**2.16685**
	Average	**4.36**	**9.533333**
	Min	**4.00**	**5**
	Max	**5.3**	**15**
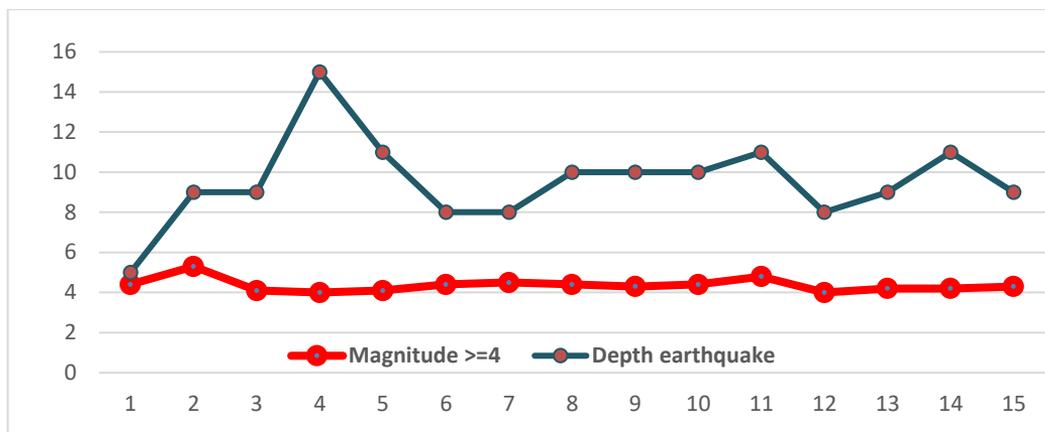
Figure 5. Earthquakes occurrence according to depth and magnitude >=4
after the earthquakes in Rieti

4. CONCLUSIONS

This paper aims to identify the rhythmic occurrence of the earthquakes in order to mitigate the disastrous effects they cause. The models used for the simulations needed for the achievement of the earthquakes generating process are very complex and report, with a margin of error, this random process which is due to several natural causes. An important role in the analysis and evolution of earthquakes is played by the statistical comparison of the simulation results with the real phenomena underlying the research system. The analysed results aim the statistical analysis of the seismic events that occurred before and after the earthquake of 08.24.2016 in Rieti. We can say that there is some similitude and rhythmic occurrence between the periods of time when earthquakes take place, considering the fact that on 09.24.2016 an earthquake occurred in Vrancea area.

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