COMPARATIVE STUDY OF EARTHQUAKE LOSSES IN ROMANIA AND TURKEY

ROMANYA VE TÜRKİYE'DE DEPREM KAYIPLARININ KARŞILAŞTIRILMASI

Emil-Sever Georgescu[1], Rifat Yarar[2] & Octav Popescu[3]

ABSTRACT

A preliminary analysis aiming to emphasize and to compare the scale, pattern and distribution of earthquake losses in Romania and Turkey is presented in the paper. The seismicity of Romania is dominated by the intermediate source of Vrancea in the Carpathian Mts., affecting about half of the territory. The earthquake disasters have been recorded in this century in 1940 and 1977. The ratio of property loss to GNP reached some 5% for the 1977 event. The shallow earthquakes of Turkey are strongly depending on the activity of North Anatolian Fault and other fault systems. The earthquake annual losses over the last 65 years are equal to 0.8% GNP of Turkey. It is obvious that such losses continued to be a heavy burden for the development of both countries. The comparative study will allow the improvement of the strategy and tactics in earthquake disaster prevention management in Romania and Turkey. In this respect, the paper suggests some possibilities of assessment of impacts, socio-economic indicators and scaling of disaster effects as a background for subsequent studies within the IDNDR. [1,2].

INTRODUCTION

The role and importance of international comparisons on earthquake disasters, the need of standardized techniques to compare the seismic losses, have been gradually recognized among the professionals of disasters management, during the last decades. [2,3,6,9].

Learning from earthquakes is already better developed in the seismological and engineering fields than in the disasters management. Thus, the aim of a study of earthquake losses in Romania and Turkey is to emphasize and to compare the scale, pattern and distribution of seismic disasters in physical, economic and social terms,

[1] Senior Res., Earthq. Engng. Dep., INCERC, Bucharest, Romania

[2] Prof. Dr. Ist.Tech.Univ., Civil. Engng. Dep. Istanbul, Turkey

[3] Civ. Eng., Ministry of Public Works and Territorial Planning, Bucharest, Romania

expressing the results in a manner appropriate for the direct use in disaster management. The authors have in mind the modelling of earthquake losses at local, sectorial and macroeconomic scale as a background for a proper funding of disaster prevention programs. [1,2].

EARTHQUAKE LOSSES IN ROMANIA

The seismicity of Romania is governed by the seismo-tectonics of its territory, while the influence of some neighbouring zones can be remarked in South, West and North. The earthquakes originating in Vrancea shake more than half of the territory, due to the large magnitudes and intermediate depth of the subduction process there.

Shallow earthquakes are expected in few local zones in West and North.

Besides the historically known great earthquakes, during this century the Vrancea earthquakes of 1908,1940,1977,1986,1990 are significant. Zoning maps have been adopted in 1952,1963,1971,1977 and 1991. (Fig. 1). Seismic intensities of 7 to 9 degrees MSK are expected for more than half of the country.[7,8].

The specific of Vrancea earthquakes is represented by the large magnitudes (M<7.5) at considerable time intervals (usually decades), the concentration of epicenters in a known but large perimeter, the directivity along the axes N-E and S-W, long period of oscillations, quite the same of intensities at distances of 100-200km from the epicentral area, the shaking felt at large distances in all countries around (Istanbul, Moscow, St. Petersburg, etc.).

Romania has an area of 237,500 sq. km and a population of 23 millions inhabitants (1991), the density of living in strong seismic zones is of 100-150 inhabitants per sq. km, but over 150 inh.per sq. km in large urban centers. During this century, from the 108 earthquakes having $M \geq 5.0$, 99 occurred in Vrancea (96 intermediate and 3 normal) and 9 in other regions.

The losses recorded in this century can be summarized as follows, for Vrancea earthquakes [2, 3, 7, 8]:

- 1940, November 10 (M=7.4), 1,000 life losses, many injured, heavy damage (ca. 10 millions current US $ or 1.1% GNP). The epicentral zone was damaged, but some towns of S-W suffered too; in Bucharest a high-rise reinforced concrete building collapsed and others were damaged.

- 1977, March 4 (M=7.2), 1,570 life losses, 11,300 injured, 32,900 collapsed and heavy damaged dwellings, other extensive damage and losses (cca. 1.7 billions US $ direct losses, 2.5 billions US $ indirect losses, although a global figure of 2 billions US $ is reported as loss in many sources; the property loss represents 5% GNP); the direct damage was concentrated in construction (housing, health, education, industry), equipment, installations, transport, materials and goods. The indirect losses represented lost production, lost exports, supplementary imports, lost tourism receipts, loans and work for recovery, etc. The bulk of damage in Bucharest was represented by the pre-1940 high-rise buildings.

- 1986, August 30 (M=7.0), 2 life losses, 558 injuries, 55,000 damaged buildings; data on economic losses not available;

- 1990, May 30 (M=6.7) and May 31 (M=6.1), 7 life losses, 100 injured, moderate damage.

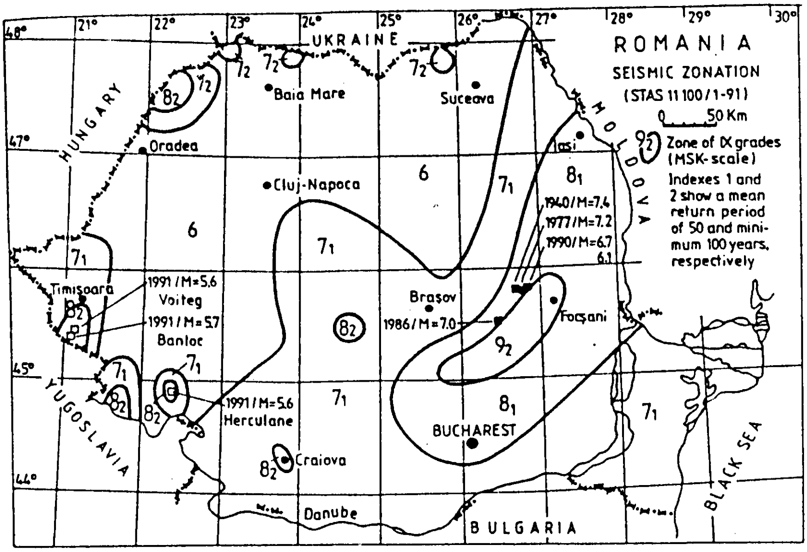

Figure 1. Seismic hazard map of Romania and the location of analysed earthquakes ■ Vrancea/1940, 1977, 1986, 1990; □ Banat/1991 [8].

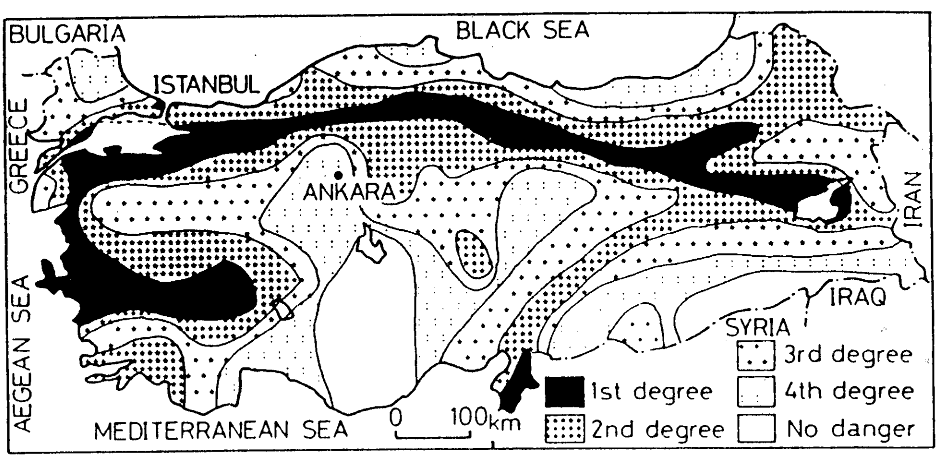

Figure 2. Official seismic zoning map of Turkey First Degree (I=IX), Second Degree (I=VIII), Third Degree (I=VII), Fourth Degree (I=VI) [1].

The losses recorded following three shallow earthquakes between July 12 and December 2, 1991 in West of Romania (several locations in Banat Zone, M~ 5.7-5.6) included:

-2 life losses, more than 30 injured, more than 4,500 people homeless and 5, 000 damaged buildings-mostly in rural settlements, where the effect of learning from earthquakes was not so evident.

According to the statistical studies on seismic activity of Vrancea region, a strong earthquake is waited around 2005±5 years [8].

The elements at risk in seismic zones include:

- 34 counties and Bucharest City are in seismic zones over VII MSK degree, while 23 counties and Bucharest City in zones of VII-IX MSK due to Vrancea source, comprising 70% of fixed assets in social, cultural and economic fields and a similar share of industrial output of the country; 60% of the country population live there;

-more than 50% of the towns with over 10,000 inhabitants are in seismic zones of VII-IX MSK degree, including cca. 65% of the urban population;

- lifelines are densely located in the area affected by Vrancea earthquakes.

The specific of seismic vulnerability of buildings was studied mostly after the 1977 earthquake. [7,10]. The traditional pattern of Romanian building types intuitively provided for life safety, even the damages were sometimes considerable. [6,9,11,12]

A new disaster pattern was introduced only by some new types of reinforced concrete high-rise buildings (not moment-resisting frames) erected mostly between 1925-1940. From this generation, a 14 story building collapsed in Bucharest in 1940, other 28 unstrengthened buildings collapsed in 1977, but some hundreds are still in service, representing a potential threat.

The concern for earthquake resistant design codes followed the 1940 earthquake impact, when the Ministry of Public Works and Communications endorsed the first regulation for protection of public works [1942, 1945]. Although the check against lateral forces was performed systematically after 1950, only in 1963 the first design code was endorsed. New editions of the design code were endorsed in 1970, 1978, 1991, 1992, learning from the effects of strong motions. Modern standards on structural design, as well as other codes we used. There is a large number of design institutes and engineers in the field. Thus, since 1950, the design and erection works have been under a state control, the earthquake protection proved to be efficient, although the limits of the technical development in the field and the limited economic resources led to some damage in 1977, even to modern structures. The strong motion data gained since 1977 allowed a new insight in the specific of Vrancea motions, well represented in the subsequent codes and zoning maps. The management of disaster prevention used the experience of 1940 earthquake, floods, natural disasters, etc; the Civil Defense Law of 1976, two State Decrees of 1978 and the Law no. 8/1977 concerning the safety of structures formed the legal background. Until 1989, the concentration of resources at central level allowed a relative success of rescue operations in 1977 with few changes in legislation in 1978. [3,8]. After 1989, the earthquakes of 1990 led to a new comprensive emergency program of the new Romanian Government, including a new zoning map, a new design code, a national program of public education for earthquake preparedness and a new Law of Disasters Prevention. [13].

The local earthquakes from Banat in 1991 proved the difficulty to provide earthquake recovery under the new conditions of decentralization and private property, but without a pertinent legislation and budgeting.

EARTHQUAKE LOSSES IN TURKEY

The seismicity of Turkey can be analysed on three active zones dominated by the North Anatolian Fault (distinct at surface on 1,000 km), the East Anatolian Fault and the Western Turkey Graben Complex. [1.4,5,6]. The focal depths are usually shallow, considerable damage is produced by the earthquakes over M=5.5 and the correlation between epicenters and locations of tectonic elements is fairly good.

The destructive earthquakes caused casualties, buildings damage and economic losses at largest extent in comparison with other natural hazards.

Within the last six decades, the number of houses damaged by earthquakes reached over 340,000 (more than 65% of the total number affected by natural disasters) and over 58,000 life losses were recorded. There is a list of about 48 destructive earthquakes along this period and one of the patterns of disasters is represented by the collapse of rural buildings erected with local materials. Although rural buildings have been used since ancient times, the systematic knowledge about their earthquake behaviour and performance was gained mostly during the studies of the last decades. [1,4,6]. The area of Turkey is 779,452 sq. km and the population is over 56,000 millions inhabitants. Seismic zoning maps have been endorsed since 1945, with new editions in 1949, 1963 and 1972, while in the 1980's new seismic hazard maps expressed with various probabilities over periods of time were prepared.[1,4]. The official zoning map (Fig. 2.) depicts four seismic zones (I=IV to IX MSK) and a "no hazard zone" (I<V MSK). The distribution of population, land area, industry and hydraulic dams with respect to the seismic hazard zones is presented in Table no. 1 [1]. Only about 50% of earthquake in Turkey take place in areas that can cause damage. Seismic vulnerability has been studied and besides the relative lower threshold of intensities causing damage for adobe and rubble masonry (specific to the East of country) there is a better behaviour of wooden framed houses (specific to the West of the country). The new types of houses using reinforced concrete have a variable resistance, and their dangerous mechanism of collapse requires further rehabilitation or control of building works. From statistical data on past losses, the earthquake related losses constitute about 0.8% GNP annually. Other detailed risk analyses based on probabilistic assumption give a 36% probability of spending 0.07% of national budget per year for rural post-earthquake reconstruction purposes, or 1.4-1.5% of the national budget every ten years for rural reconstruction after disasters [1,5].

Considering a probability of 0.63% to have an earthquake of I=IX every 5 years, the envisaged damage caused only to buildings is of 200 millions US$ or 1.5 trillions TL, depending on the characteristics of the region.[4].

The recent Erzinçan earthquake of March 13,1992 produced direct losses of 3. 3 trillions TL, while the estimated indirect losses may reach 1.5-2 times this value.[4].

There is a historical experience and some early technical and disaster prevention legislation in Turkey, but the modern approach started after the 1939 December 26, Erzinçan earthquake and subsequent chain shocks until 1944. The toll of lives and destroyed houses triggered the enactment of a special law in July 1944, followed by the

Table 1. Distribution of population, land area, industry and hydraulic dams in seismic zones of Turkey.

Earthquake zone	Population (%)	Area (%)	Big industrial centers (%)	Hydraulic dams (%)
First degree I > IX	22	14.8	24.7	10.4
Second degree I=VIII	29	28.4	48.8	20.8
Third degree I=VII	24	28.8	12.0	33.3
Fourth degree I=VI	20	19.4	12.6	27.1
No hazard I<V	5	8.6	1.7	8.4

1959 Natural Disasters Law, the 1968, 1971 and 1983 Laws and Regulations for related matters.[1,4,6]. There is a well stated structure of Government and Provincial Councils in charge with disaster mitigation and relief, and also some resources allocated in special funds for a continuous preventive activity. There has been program of public earthquake education since 1974.Technical regulations for earthquake resistant design were endorsed in 1945, 1949, 1953, 1961, 1968 and 1975 [4]. The efforts in the field of natural disasters prevention are coordinated from technical point of view by the Ministry of Public Works and Settlement, Earthquake Research Institute, Technical Universities etc. where a large number of high level professionals is working.

The Turkish National Committee for Earthquake Engineering plays a great role in the mitigation of seismic losses through research programs and cooperation among public and private organizations.

THE EARTHQUAKE LOSS ANALYSIS USING STATISTICAL DATA, MODELLING OF LOSSES AND ECONOMETRIC SCALING

The use of comprehensive analysis of seismic risk is not always possible due to the lack of pertinent data. In such cases, the use of simpler methods can provide policy elements for disaster prevention management. The visibility of earthquake losses impact in current statistics depends on the following elements [3]:

• the direct losses impact:

-the size of damaged area, the vulnerability of elements at risk, the actual damage, life lose and injuries, the incidence of secondary or higher order disasters;

- the ratio of damaged area vs. the country area, the ratio of suffering population vs. the whole population, the share of the affected economic branches in the local, regional and national product and in foreign trade income;

- the density of population, the kind of settlements, socio-economic facilities and economic output in the affected area;

- the value of property losses and their sectorial distribution, the size of the national wealth and national product and their ratio;

• the indirect and long-term losses impact

- the type of economic system and the input-output relationships between the major sectors of the country's economy as well as the level of development (UN classification of GDP/GNP per capita);

- the trend and patterns of the country's economy and the conjunction of international trends;

- the existence of a disaster prevention legislation and loss recovery system using public or private funds.

Besides the assessment methods used in economics (when data are available), a series of direct or composite indicators in physical or monetary expression have been derived elsewhere, relating the losses to the regional characteristics published as inventories and statistics [3].

One of the most used overall expressions is the ratio of losses vs. GNP, since the ability, to rebuild and recover the affected zones is function of the nominal economic power of the country. In order to allow a relative assessment of the loss importance for different countries, Georgescu and Kuribayashi [3] developed a special indicator of global econometric scaling using knowledge about earthquakes (GESKEE Disasters Scale, Equation 1):

$$\log\ GESKEE = \log\left(\frac{Earthq.Loss}{GNP_{country}} \cdot \frac{GNP_{USA}}{GNP_{country}}\right) \qquad (1)$$

Using the data on 26 earthquakes since 1906 in the World, the clustering of results suggested a good correlation between the following factors:

- the level of economic development according to UN classification on three categories;

- the size of earthquakes and the specific of the affected zone;

- the specific ranges of GESKEE indicators;

- the patterns of recovery in terms of duration, consequences and need of international aid.

There is a general trend of chronological improvement in the country's relative ability to cope with disasters as the development becomes significant, although the local disaster effects may occur again if the technical advancement does not follow the economic development.

A preliminary assessment of the size and impact of the March 13, 1992 Erzinçan earthquake, gives reasonable results on the GESKEE Disasters Scale, locating the disaster in the same broad category with Romania 1940 and 1977, Mexico 1985, Yugoslavia 1979, Algeria 1980 earthquakes, although there are significant differences of size [3].

The modelling of territorial distribution of losses, which is necessary in order to assess the scale of damage as an input for the econometric methods is also possible using simplified methods. The shape and size of areas subjected to specific intensities can be approximated function of parameters learned from past earthquake. For Romania and Turkey the elliptical isoseismal lines seem to be appropriate, at least for disaster management purposes, but the size of areas and causal relationships are different [3,6]. The attenuation relationships for Turkish earthquakes were studied for almost all destructive events [6], but for the Romanian, Vrancea earthquakes the data are still contradictory [2,7,8,11]. For modelling purposes, one can, however, adopt some approximate laws reflecting the pattern along some profiles. In this respect, the investigation of past losses in each district of Romania is necessary, in physical and economic expression [2,3].

CONCLUSIONS OF THE PRELIMINARY STUDY OF EARTHQUAKE LOSSES AND DISASTER MITIGATION MEASURES IN ROMANIA AND TURKEY

The study of earthquake effects in Romania and Turkey points out similarities and differences concerning the scale, pattern and distribution of seismic losses.

In Romania, the intermediate, large earthquakes produced a significant number of life losses, injuries, damage and economic loss on large urban and rural areas (over 100,000 sq.. km each time), mostly in the two worst situations during this century.

At country level, in Turkey the destructive shallow earthquakes led to larger individual and a cumulative number of life losses, injuries, damage and loss, mostly in rural areas, due to more than 48 earthquakes during this century. The affected zones were not so large each time, but the higher exposure, the recurrence of strong motions and the large stock of vulnerable buildings contributed to the disasters.

In both countries the disasters proved that the mitigation of losses can be obtained only gradually, as a component of the socio-economic development with adequate financing.

The recurrence of concentrated disaster situations such as in Bucharest in 1977 and in Erzinçan in 1992 proved the need of a strict control of the seismic resistance and quality of existing buildings belonging to all generations, especially the ones damaged in past earthquakes and unstregthened.

The present level of development of Romania and Turkey requires to be concerned not only about the life safety but also about economic losses, in direct and long-term consequences. In this respect, a joint research is necessary for further comparative loss analyses and disaster mitigation, considering the following aspects:

- there is a need for standardized loss indicators;

- the modelling of losses shall be calibrated to the past earthquakes, taking into account the use of figures for assessing the budget for management of disasters prevention;

- the disaster prevention and mitigation strategy shall be in good agreement with the level of development and urbanization and based on long-term plans. The earthquake preparedness education of specialists, administrative staff, government officials, politicians, local leaders, builders and population is necessary.

-Romania must learn from the experience of Turkey both in legislative and operational terms, under the conditions of a market economy, a decentralized control of investments, urban and rural management and development, in order to avoid the difficulties and critical situations which may occur due to the ignorance or lack of technical control since the boom of private construction in Romania is likely to escape the local technical control;

- both countries shall develop and enforce the management of disaster prevention and mitigation at territorial level, providing adequately trained personnel for emergency operations, to work within the efficient interval for rescue, knowing in advance the possible damage and local resources;

- the experience of Turkey concerning the reconstruction after the Erzurum-Kars earthquake of 1983 with the large participation of private companies can be used for the reconstruction of the rural zones affected by the 1991 Banat earthquakes in Romania;

- the experience of Romania concerning the design and good behaviour of industrialized structures erected on a large scale in seismic zones shall be used for the improvement of the building stock in rapidly urbanized zones in Turkey;

- the ways of creating disaster rehabilitation funds through excise taxes required from state and private companies, credits and mortgage payments in Turkey is of great interest for Romania. The size of those funds will be better correlated with the actual needs, if the comparative study of losses will be performed.

- all the progress in the field of loss assessment and disaster prevention should be mutually available in the framework of IDNDR.

REFERENCES

1. Yarar, R. (1986), "Legislation framework relative to the mitigation of seismic risk in Turkey", Proc.. UNCRD International Seminar, Nagoya, Shizuoka-Tokyo, Japan, Vol. 2, pp. 105-138.
2. Georgescu, E. S., Kuribayashi, E. (1992)" Study on seismic losses distribution in Romania and Japan", Proc. 10-th World Conference on Earthquake Engineering, Vol. 10, pp. 5977-5982, Madrid, Spain: IAEE Balkema, Rotterdam, Holland.
3. Georgescu, E. S. (1992) "The seismic disaster mitigation and anticipated earthquake preparedness, analysing the earthquake resistivities of densely populated urban and rural centers", Research Report within a JSPS Fellowship, Toyohashi University of Technology, Aichi, Japan.
4. Gülkan, P., Ergünay, O.. (1992) "Case study of Erzinçan Earthquake of 13 March 1992", UNDRO Disaster Management Training Program Turkey Country Course, June 1992, Ankara, Turkey..
5. Erdik, M. (1991) "Urban Earthquake Hazards, Risk and Mitigation", Fifth Conference on Soil Dynamics and Earthquake Engineering, University of Karlsruhe, Germany.
6. .Ohta, Y. (Editor, 1983) "A Comprehensive Study on Earthquake Disasters in Turkey in View of Seismic Risk Reduction", Hokkaido University, Sapporo, Japan.
7. Sandi, H. et al. (1978). "Lessons from the Romania Earthquake of 4 March, 1977", Proc. 6-th European Conference on Earthquake Earthquake Engineering, Dubrovnik: EAEE.
8. Radu, C., Georgescu, E.S. (1992) "Necessity of Training and Education in an Earthquake-Prone Country", 6-th International Seminar for Development Planning and Disaster Prevention Management, IDNDR Symposium on Earthquake Disaster Reduction Technology UNCRD-IISEE, Tsukuba, Japan.

9. Georgescu, E.. S. et al. (1979) "Low-cost traditional dwellings for rural areas in Romania". Proc. 7-th UNESCO Seminar on Earthquake Engineering, Istanbul, Turkey: TNCEE
10. Sandi, H. (1984) "A report on vulnerability analysis carried out in the Balkan Region", Proc. 8-th World Conference on Earthquake Engineering, Vol.VII, pp.. 647-654, Englewood Cliffs, New Jersey, U.S.A., Prentice Hall.
11. Tezçan, S., Yerliçi, V., Durgunoglu, H. I. (1977) Romanian earthquake of March 4-th, 1977", June, Bebek, Istanbul, Turkey.
12. Georgescu, E. S. (1987) "Present aspects of the aseismic protection of rural buildings in Romania", Proc. 13-th Regional Seminar on Earthquake Engineering, TNCEE, vol.2, pp. 561-583, Istanbul, Turkey.
13. Vataman, O., Georgescu, E. S. "The Romanian Program for public earthquake preparedness", Proc. 10-th WCEE, 19-24 July 1992, Madrid, Spain, Vol. 10, pp. 6065-6068, Balkema, Rotterdam, Holland

ROMANYA VE TÜRKİYE'DEKİ DEPREM KAYIPLARININ KARŞILAŞTIRILMASI

Emil-Sever Georgescu, Rıfat Yarar, Octav Popescu

ÖZET

Bu makalede Romanya ve Türkiye'deki deprem kayıplarının boyutunu şeklini ve dağılımını karşılaştırmayı ve önemini vurgulamayı amaçlayan bir ön çalışma sunulmaktadır. Romanya'nın sismisitesi, ülkenin yaklaşık yarısını etkileyen ve Karpat Dağları'nda yer alan Vrancea kaynağı tarafından belirlenmektedir. Bu yüzyılda, 1940-1977 yılları arasında depremler kaydedilmiştir. 1977 depremindeki kayıpların milli gelire oranı %5'e ulaşmıştır. Türkiye'deki sığ depremler büyük ölçüde Kuzey Anadolu fay hattı ve diğer fay sistemlerinin aktivitesine bağlıdır. Son 65 yıl içinde, yıllık deprem kayıpları Türkiye'nin milli gelirinin % 0.8'ne eşittir. Bu tür kayıplar her iki ülkenin de gelişimi için ağır bir yük olmaya devam edeceği açıktır. Karşılaştırmalı bir çalışma, Romanya ve Türkiye'deki deprem felaketlerinin önlenmesi için strateji ve taktiklerin geliştirilmesini sağlayacaktır. Bu anlamda IDNDR kapsamında yer alacak daha sonraki çalışmalara da temel olmak üzere, bu çalışmada deprem felaketinin etkilerinin sosyo-ekonomik göstergelerinin ve büyüklüğünün belirlenmesini mümkün kılacak bazı değerlendirmeler önerilmiştir.