A REVIEW OF SOCIO-ECONOMIC CONSEQUENCES, LOSSES AND HUMAN CASUALTIES OF THE 1977 VRANCEA, ROMANIA EARTHQUAKE

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The present paper is dedicated to Dr. Horea Sandi, a prominent scientist of Romanian structural and earthquake engineering, to honor his endeavours dedicated to the research school created in INCERC and in Romania, to his contribution in EAEE Working groups, to his life - time work on a conceptual and applicative framework in seismic risk and vulnerability analysis to fit specific patterns of Vrancea and Romania conditions.

The 80-th anniversary of Dr. Horea Sandi is a perfect opportunity to review results from our recent research related to the consequences of the 1977 Vrancea earthquake, 35 years after its occurrence, as the authors benefited of first hand knowledge, warm guidance and cooperation from Dr. Sandi along decades.

ABSTRACT

Although its socio-economic disaster pattern was obvious, the March 4, 1977 Vrancea, Romania earthquake was studied mainly in seismological and earthquake engineering terms. In 1977, the loss data released in Romania, referred to 32,900 collapsed or heavily damaged dwellings, 35,000 homeless families, thousands of damaged buildings, many other damages and destructions in industry and economy, 1,578 people killed, 11,321 people injured (with 90% of the killed and 67% of the injured being in the city of Bucharest). The Romanian government reported the economic losses from this event in December 1977, as being US$ 2 billion. For a long time, the evaluation of human casualties vs. collapse pattern of buildings in 1977 was not addressed and we still miss integral data. The recovery and reevaluation of economic and social impacts of the 1977 disaster was a concern of the authors, with the intent to better understand its consequences and prepare a new strategy of seismic risk reduction in view of future earthquakes in Romania, and in order to fill that gap the authors recovered many unpublished and obscure data.

Keywords: building damage; collapse and casualty patterns; territorial loss distribution

REZUMAT

Deşi specificul de dezastru socio-economic a fost evident, cutremurul de Vrancea de la 4 martie 1977 din România a fost studiat în principal cu privire la seismologie şi ingineria seismică. În 1977, datele date publicităţii despre pierderile la cutremur se refereau la 32.900 clădiri de locuit prăbuşite sau grav avariate, 35.000 familii rămase fără locuinţă, mii de clădiri avariate, multe alte avarieri şi distrugeri în industrie şi economie, 1.578 pierderi de vieţi, 11.321 răniţi (90% dintre pierderile e vieţi şi 67% dintre răniţi fiind in Bucureşti). În decembrie 1977, conducerea României a raportat 2 miliarde de dolari pierderi economice ca urmare a acestui eveniment. Mult timp nu s-au studiat efectele asupra oamenilor în raport cu specificul prăbuşirilor din 1977 iar datele complete nu sunt încă disponibile. Recuperarea şi reevaluarea impactului economic şi social al dezastrului din 1977 i-a preocupat pe autori, cu intenţia de a înţelege mai bine consecinţele sale şi a pregăti o nouă strategie de reducere a riscului seismic pentru a face faţă viitoarelor cutremure din România; pentru a compensa lipsa de date, autorii au recuperat multe date nepublicate, aparent nesemnificative.

Cuvinte cheie: avarii clădiri; specific prăbuşiri şi efecte asupra oamenilor; distribuţia teritorială a pierderilor

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1. DATA ON MARCH 4, 1977 DAMAGE, LOSSES AND IMPACT AND RATIONALE FOR THEIR RE-EVALUATION

The sources for the data on March 4, 1977 Vrancea earthquake losses were the initial official communiqués, local technical books, papers and some reports by international specialist delegations. Damage referred to 32,900 collapsed or heavily damaged dwellings, tens of thousands of damaged properties, many other damages and destructions in 763 commercial and industrial units and other effects in the whole spectrum of the economy. Casualties were reported in 1977, in rounded figures, as 1,570 deaths, 11,300 injured, with 35,000 homeless families. Visiting foreign specialists received summary information and photographs of collapses from local officials, and they were also allowed to visit some of the damaged areas. These post-earthquake reconnaissance reports and studies presented seismological, engineering issues and some disaster management aspects and were made available to Romanian staff and specialists of the time (Berg et al., 1977; Fattal et al., 1977; Moinfar, 1978; Tezcan et al., 1977; EERI Report, 1977; JICA Report, 1977; AIJ Report, 1978 etc.). The earthquake engineering research developed afterwards was to a great extent done by Sandi (1982, 1984, 1985, 1986, 1999), Sandi et al. (1978, 1990, 1994, 2002, 2007). The Vrancea earthquakes of 1986 and 1990 provided additional knowledge while causing mostly non-structural damage, although they also inflicted a small number of casualties (Georgescu and Pomonis, 2010, 2011).

Some papers favorably appreciated the management of the emergency situation in Romania in 1977 comparing it in contrast to the earthquake in Nicaragua in 1972 (Jones and Avgar, 1977; Ebert, 1986). On the other hand members of the US Congress criticized Romanian authorities for the aid distribution to population (US Congress Records, 1977).

In 1977-78 a special action was undertaken by the Central Institute ICCPDC-Bucharest to collect data on damage from ministries and counties, but most of these data were considered classified material and were not made known to the public. In 1978, the first edition of an extensive four volume report was published, with limited circulation, addressing the damage incurred and lessons learned, with some data on the territorial spread of damages (ICCPDC, 1978). This was followed in 1982 by the publication of a special volume on the earthquake which contained the results of detailed damage surveys and extensive engineering and engineering seismology studies (Balan et al., 1982). However, the economic value and social effects of the earthquake were never discussed in detail and were generally given limited consideration in all of the above reports and official communiqués. Some ICCPDC reports that include a preliminary valuation of damages became available only after the 1990's.

The World Bank Report of 1978 was the only contemporary report addressing the socio-economic aspects on the 1977 earthquake in some detail referring to the government's US$ 2 billion loss estimate and including more detailed figures on loss by economic sector and impact considerations. This report was used as background information for a loan to Romania (World Bank, 1978) and was neither quoted in local references nor available in Romania until 1992. The US Foreign Disaster Assistance Office (OFDA, 1988) indicate the same total loss, while others (Munich Re, 1998; Coburn and Spence, 1992; 2002) suggest only some US$ 800 million loss.

Many direct and indirect loss data were presumably underestimated or neglected in 1977, while other economic losses were only briefly described (World Bank, 1978; ICCPDC, 1978). Although the consequences of the earthquake were truly significant and the Romanian authorities used this argument to obtain foreign loans and assistance, the immediate and long-term impact on development were not treated as a matter of public concern and debate in Romania.

However, many international analysts referred to the 1977 earthquake in studies on East European economies and their first international concern about the 1977 disaster impact was related to Romania's capacity to pay its debts and secure its economic growth (Jackson, 1977, cited in Burakow, 1980). After the fall of the communist regimes, several retrospective studies estimated that the 1977 earthquake greatly contributed to the slow-down

of Romania's economy (Deletant, 2002; Deletant and Ionescu, 2004), with even KGB defectors making similar allegations (Andrew and Gordievsky, 1990).

All former impact evaluations considered the ratio of losses to the Gross National Product-GNP (or to the Gross Domestic Product-GDP), whose size was difficult if not impossible to be accurately estimated in US$ or any foreign currency at the time of earthquake. The GNP or GDP evolution of Romania until 1989 and the GNP of all East European countries have been frequently re-evaluated (Jackson, 1985, Lancieri, 1993).

2. DETAILED DATA ON 1977 EARTHQUAKE DAMAGE AND ECONOMIC LOSS

2.1. Data of World Bank Report (1978)

The categories, sectors and values of the damage (loss) caused by the 1977 earthquake are compiled from the 1978 World Bank report and presented in Table 1. The World Bank Report of 1978 indicates that the data was based on an immediate estimation by the authorities of the time. It seems that an Aggregate Damage Report by the Romanian Ministry of Finance was sent in July 6, 1977, but there is no indication in the report about how dollar values were obtained and by whom.

According to the report, out of 40 counties, 23 were strongly affected, with Bucharest recording the highest loss, accounting for 70% of the total, i.e. US$ 1.4 billion.

Counties in the south-east of the country (Teleorman, Dolj and Prahova) but also in north-east (Iasi, Bacau) suffered significant damage. The World Bank Report concludes that the overall effect of the earthquake on the housing sector of Romania was

- 156,000 apartments in urban zones and 21,500 houses in rural zones were destroyed or very seriously damaged;
- 366,000 apartments in urban zones and 117,000 houses in rural areas needed to be repaired.

Table 1.

Inventory of damage (loss) caused by the March 4, 1977 earthquake (Source: World Bank Report No. P-2240-RO, 17 May 1978, grouped in direct and indirect losses by the authors)

No.	Sector	Total damage value million US$	Of which			
			Direct			Indirect
			Construction (buildings, water supply)	Equipment, Installations and Transport	Raw materials, intermediate and consumer goods	Production losses
1	Industry	447.3	102.7	20.0	28.4	296.2
2	Agriculture	124.4	46.4	10.7	17.0	50.3
3	Transport, Communications and Retail Trade	93.2	52.1	14.4	14.7	12.0
4	Health, Education and Socio-cultural	167.3	147.5	18.1	-	1.7
5	Housing	1,032.8	1,015.0	17.8	-	-
6	Local Industry, Utilities and Construction	87.6	56.4	23.3	3.4	4.5
7	Miscellaneous Private Goods	95.4	-	-	95.4	-
8	**Total**	**2,048.0**	**1,420.1**	**104.3**	**158.9**	**364.7**

The sum of the above is 660,500 dwelling units or around 11% of Romania's dwelling stock at the time. These data were not commonly discussed in Romania, where the figure most frequently mentioned is that of 32,900 destroyed or heavily damaged dwellings and occasionally a figure of 182,000 damaged dwellings is also mentioned. Using other descriptive data from the World Bank Report, the values in Table 2 have been obtained.

From Tables 1 and 2 it results:

- the total reported losses account for US$ 2.048 billion (US$ 1.683 billion in direct losses and US$ 0.3647 billion in indirect-production losses);
- the loss to constructions represented 69.4% of the total and 84.3% of the direct losses; the housing sector losses (US$1.0328 billion) represented 71.4% of construction losses, or 61.4% of the direct losses and 50.4% of the total losses;
- the loss in industry represented 21.8% of the total; the indirect-production losses were prevalent in industry and agriculture, while in transport, communication, health, education, local industry the loss to constructions was prevailing;
- other non-reported, indirect losses, could amount to around US$ 2.4953 billion as roughly assessed in Table 2; with the total indirect losses reaching as much as US$ 2.860 billion and the ratio of indirect to direct losses being 1.7;
- by adding the reported and estimated losses, the total possible loss could reach US$ 4.5433 billion.

The fact that the damage from the 1977 earthquake was extensive is also evidenced by the fact that Romania received aid from 55 countries and 12 organizations. Other long term socio economic consequences of damage remain to be estimated (Georgescu and Pomonis, 2007, 2008).

2.2. Data on territorial distribution of losses based on ICCPDC reports, Romania (1978)

In the ICCPDC reports issued by each affected ministry and county separately, the overall amount of losses is given in physical units and reaches values of as much as 32,897 collapsed or demolished dwellings, 34,582 homeless families and 763 industrial units affected and many other damages in all sectors. The ICCPDC reports are internal reports with detailed data that were produced by the authorities at the request of the Central Government. The aggregation of the loss was made at the end of 1978, in the local currency (Romanian Lei). Damage is given in number of collapsed and damaged dwellings or apartments, as well as in number of strengthening and repairs needed, and units of social

Table 2.

Value of other indirect losses for March 4, 1977 earthquake, indicated in World Bank Report No. P-2240-RO, 17 May 1978 and / or evaluated by the authors

No	Other indirect losses	Value (million US$)
1	Lost exports over two years	250.0
2	Supplementary exports to replace lost equipments and expand construction industry capacity	350.0
3	Tourist receipts loss in 1977	30.0
4	Loans and credits on different terms	190.3
5	Total I (World Bank data)	820.3
6	Unpaid extra days work for recovery, donations, contributions (20 billion Lei, converted by the author at 20 lei/US$)	1,000.0
7	Repair works of damaged houses in own households (author's evaluation)	675.0
	Total (World Bank data and other estimations)	**2,495.3**

and cultural buildings in 19 counties plus Bucharest City. In total there were:

- 742,259 collapsed or damaged dwell-ings, out of which 35,600 dwellings were collapsed or condemned (4.8%), 351,835 dwellings to be strengthened (47.4%) and 354,824 dwellings to be repaired (47.8%);
- 8,228 social-cultural units lost and damaged, representing 28.8% of national stock.

The total damage value from these two categories is Romanian Lei 3,725,177,000, out of which Bucharest damage accounts for Lei 1,553,362,000 (excluding social-cultural buildings of ministries and central institutions that have not been reported for Bucharest). Housing represented 90.45% of this total loss, while social and cultural buildings represented 9.55%. Loss data from 20 ministries having assets in 25 affected counties amounts to Romanian Lei 3,523,194,000. The 763 industrial units included 2,491 objects and 1,077,000 square meters of production floor area. The territorial loss was heavy in many counties as percentages of damage indicate both in physical units and values. Thus, the total loss derived from the ICCPDC reports (December 1978) reaches Romanian Lei 7,248,371,000.

The ICCPDC reports mention that loss evaluations considered the legal system of prices based on assumptions of cost for repair and strengthening, while some loss was not considered at all, as for example: debris removal and demolition, temporary propping, private goods, supplementary transport, relocation, medical treatment in hospitals, epidemics prevention, disabled and orphans pensions, salaries during business resumption, unpaid extra work etc. There were some counties and ministries that did not report losses, although it was known they sustained some damage.

In terms of the relative composition of the losses, there is some similarity as to the share of housing in the total ICCPDC loss, but Bucharest's loss share cannot be compared since it is given only with respect to housing and socio-cultural. The above can thus be considered as a first level estimate of the actual 1977 loss expressed in Romanian Lei. In order to convert these to US$ and compare them with other data, we must check their completeness, relevance and consider the then applicable exchange rates.

Figure 1 shows the damage distribution for each of the 20 affected counties' 1977 dwelling stock in buildings that were destroyed (collapsed or to be demolished), needed strengthening or needed repair (lighter damage), respectively. We use the colours

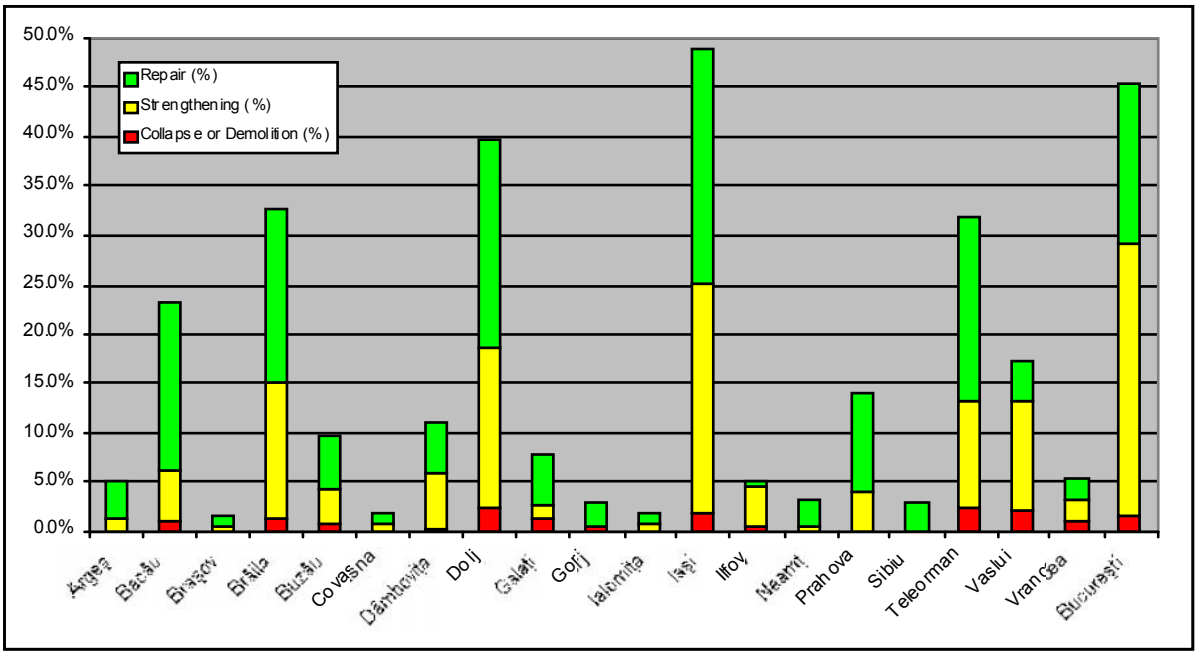

Fig. 1. Territorial distribution (20 affected counties) of ratios of dwelling units in "destroyed", "to be strengthened" and "to be repaired" buildings vs. the total stock of dwelling units in 1977 (%) (further details in Georgescu and Pomonis, 2007, 2008)

red, yellow and green, as this is an accepted international convention to portray the three damage-building safety levels during post-earthquake damage surveys. For the county of Gorj the number of dwellings in the category "to be strengthened" has not been reported.

This territorial distribution of damages gives us a better understanding and may contain many hidden messages that we need to explain. The loss was heavy in many counties and its geographic distribution surprising, with limited damage in the epicentral region and extensive damage in distant counties. Each county's damage distribution has some meaning, while the sum of all situations, expressed as the proportion of affected dwelling units compared to the total dwelling stock of each county in 1977, may give a broader overview of the severity of the damage in each county and Romania as a whole.

In comparison with usual attenuation patterns, one may wonder why counties in the epicentral region were largely unaffected, when counties more than 100-km away, suffered nearly 50% damage rates. For example, Iasi County (48.8% affected dwellings) and Bucharest City (45.4% affected dwellings) are on the first places, although situated at considerable distances from the Vrancea seismogenic zone. The large number of old buildings in Iasi and the long-period effects on slender buildings in Bucharest are among first explanations at hand. Dolj County (39.6%) even further from Vrancea is on the third place, something that to this day has not been fully explained and a combination of the previous two causes can be put under debate, without full arguments for each. One reason may be that Dolj County was in the lowest zone of the Romanian earthquake code in the 1963-1977 period (zone of intensity VI).

Braila County was the 4th worst affected county in 1977 (32.5% affected dwellings), but neighbouring Galati County was not affected to the same extent (11th with 8% of its dwellings affected). Braila and Galati cities (217,000 and 300,000 people respectively), are built on „loess" which in the past has caused lots of damage (due to ground subsidence) related to the rise of the water table, rise of phreatic waters from the Danube River which is crossing the cities or from leaks (from the canals), many old tunnels which caused damage before and during the earthquake. Also many houses are from load-bearing masonry in these two counties. Galati has newer buildings, many areas were rebuilt as the industries were developed. Could it be also that the differences in damage between Galati and Braila may be explained by the effect of loess that is more extensive in Braila County, since the Danube is crossing the whole county, while in Galati county the river is forming the southern border of the county? Some of the difference could also be due to attenuation patterns, although Galati County is somewhat nearer to the Vrancea source zone than Braila county.

In the south, the towns of Alexandria and Zimnicea (in Teleorman County, the 5th worst affected county) had an older housing stock and being rural areas had a large number of low-income housing. In these areas, many houses were made from a mixture of earth and wood and the bricks were made until in the 60's from local clay in the outskirts of each village. The toughness of the bricks depended of how much fuel and straw, was available for the local kilns. The mortar used at the time did not have enough lime. In many cases villagers used sand and clay mortar and after the 50's more lime, cement etc. and gradually industrial bricks. Some of the difference could also be due to attenuation patterns, although how can we explain the fact that Ilfov which is nearer Vrancea than Teleorman was not seriously affected? Ilfov was also a rural county though clearly of higher income levels due to its proximity to Bucharest.

Prahova County, that is 7-th worst affected county with 14% affected dwellings and was also seriously affected by the 1940 earthquake and has always been in zone of intensity VIII of every version of the Romanian earthquake codes. Vrancea County, that includes the nominal epicenter, is 13th on the list of affected counties (with only 5.6% affected dwellings). As a possible explanation, Vrancea County was devastated in the 1940 earthquake and much of its housing was rebuilt after 1945 incorporating ring-beams, with more extensive use of brick masonry instead of adobe. Vrancea County has always been in the highest zone of the Romanian Earthquake Code (the county is found within the zones of intensity VIII and IX), and although base shear forces may not be that great as experienced

during 1977, this must have contributed in the reduction of damage in Vrancea County.

Buzau County has 9.7% affected dwellings. Buzau city on the other hand suffered much more damage in spite of the fact that it is further from the epicenter, founded on better soil and had better maintained buildings. The effects of the earthquake were strongly felt in the Buzau river valley (towards the hills): Patarlagele, Viperesti, Cislau, Calvini, Chiojdu etc. This can be related to the earthquake rupture trace, which has developed along a line towards the S-E, in Buzau County.

2.3. Comparison of Detailed Losses

The number of damaged housing units derived from the ICCPDC reports is 12.4% greater than in the World Bank report that was published somewhat earlier. In order to compare the total ICCPDC reported loss in Romanian Lei with the World Bank one in US$, we need to address the exchange rate issue. At the time of the earthquake in Romania different Lei to US$ exchange rates were used (e.g. for internal trade, for external trade etc.). For international comparisons the GNP of countries with Centrally Planned Economies (CPE) was obtained in that epoch by the World Bank from domestic data using applicable exchange rates (in the case of Romania an exchange rate of 20 Lei per US$ was used in 1977). A review of the various estimates of the GNP of CPE''s is made by Lancieri (1993). The estimates made by various western bodies and authorities are notoriously different, and for example in the case of Romania the estimate of its 1980 GNP ranges from 34 to 103 billion US$.

If the losses in US$, communicated by the Romanian Communist Party in December 1977, recorded by the World Bank report, and the ICCPDC ones in Romanian Lei had been equivalent, a rough conversion would lead to a rate of 3.53 Lei per US$, which is lower than any exchange rate used at the time. Therefore we tend to believe that some component of loss was added at central level, when aggregation was made for communi-cation to the World Bank. There is a certain feeling that the number of damaged elements and floor area that was heavily damaged is acceptably described in inventories, but other loss values are missing in the final value of the preliminary ICCPDC loss table. We may suppose that the missing losses were, at least, those mentioned before, as well as others that appear in the World Bank Report of 1978 but were not reported by ICCPDC for unknown reasons. The exchange rate for foreign trade (ca. 20 Lei per US$ in 1977) was considered at the time as the one that was closer to the true value of the local currency. For comparison if a Romanian citizen brought US$ into the country the conversion rate into Lei was of 4.970 per US$ in 1977 and 4.559 per US$ in 1978. This exchange rate was at the time considered as quite unfair.

There are many reasons to believe that Romania's 1977 regime possibly reported a smaller damage extent and impact because:

- the authorities were not sufficiently prepared to assemble detailed data and investigate the loss in all aspects; what was at hand was the direct loss on buildings and infrastructure in social-economic and industry sectors and only some indirect losses; the request for data from the local authorities was mainly focused on such items;
- the calculation of loss or replacement costs relied on conventional average apartment floor areas and fixed costs for repair and strengthening, that were grossly under-estimated and unrealistic; later on, it was common knowledge that construction enterprises worked at a loss for such time consuming works; the calculated costs were not for upgrading the damaged buildings but to bring their strength to the situation as before the earthquake;
- a greater reported damage and loss would have been considered by the regime leaders as an embarrassment, reports about huge losses could reduce the country's credit rating and place in doubt its ability to pay foreign debts and such weakness could have been exploited by the Soviet Union seeking to regain control;
- admitting to a major loss and impact would have tarnished Romania's image.

We are conscious that there is a contradiction between the finding of a too advantageous exchange rate and the reasons of a smaller loss reporting presented above. Only further evaluations may bring us closer to some truth.

2.4. Alternative Dollar GNP Estimates for Romania and revised loss to GNP ratio

The Romania annual GNP series from the World Bank or United Nations or other statistical books or almanacs are quite different. The GNP of Centrally Planned Economies-CPE's has been an object of study for years, because their Systems of National Accounts were different (Jackson, 1985). Lancieri (1993) published a new study on CPE's GNP and concluded that past values of GNP per capita for CPE's during 1970-1990 were by far too large. Selecting the available data on Romania's GDP or GNP, we obtained alternative results as shown in Table 3.

In table 3 the exchange rate was different, according to purpose and countries (Jackson, 1985):

- in 1977, the official exchange rate for Romanian Lei per US$ was of 4.970 , in 1978 - 4.559, in 1979 to 1983 it was 4.470; it was used for foreign tourists from western countries;
- in 1977-1980, the non-commercial exchange rate for Romanian Lei per US$ was of 12.000;
- in 1977, the commercial exchange rate for Romanian Lei per US$ was of 20.000, in 1978 it was 18.355, in 1979-1980 it was 18.000 and in 1981-1982 it was 15.000.

Since the Romanian officials favoured the use of commercial rates for GDP conversion, Jackson, 1985, considered this rate as closer to the truth.

According to Table 3, depending on reference GNP values, we have:

Table 3.

Alternative values for Romania's GDP or GNP in 1977 and corresponding loss to GNP ratio for the March 4, 1977 earthquake (Georgescu and Pomonis, 2007, 2008)

GDP or GNP in billion Romanian Lei and source of data	Exchange rate in Ro Lei per US$	GDP or GNP value in billion US $	Direct loss ratio, using loss data from WB Report	Total loss ratio, using data from WB Report
512.9 (GDP in current prices, from Romanian data expressed in SNA, Jackson, 1985)	20	25.645	6.56%	7.99%
530.1 (GDP in current prices, Alton 1981, cited in Jackson, 1985)	20	26.505	6.35%	7.72%
World Bank Report, 1978 (GNP per capita x population)		34.126	4.93%	6.00%
World Bank Atlas, 1977-78 (GNP per capita x population)		33.121	5.08%	6.18%
Marer's per capita GNP data for 1980 (cited in Lancieri, 1993), discounted for 1977 with 10% average growth. Alternatives: - 15.7 % GDP deflator - 19.2 % CPI deflator		 22.172 21.557	 7.59% 7.80%	 9.23% 9.50%
World Bank, 1977 data, reduced by the author by 20%, using information from Lancieri, 1993		25.496	6.66%	8.03%

- the range of direct loss to GDP or GNP ratio in 1977 could range from 4.9% to 7.8%;
- the range of total loss to GDP or GNP ratio in 1977 could range from 6.0% to 9.5%;

Using the total possible loss estimated by the authors (US$ 4.5433 billion) and the alternatives of GNP, the range of total possible loss ratio to GDP or GNP in 1977 could range between 13.3% and 21.1%.

2.5. Loss to GNP ratio and comparisons with other countries

In the economic production mechanism, the loss of capital assets will reduce the economic output, while the loss of other elements at risk will require resources for recovery, slowing down the development process. Ribaric (1982), Kerpelman (1990), Klyachko (1994) and Chen (1997) used the ratio of losses to GNP for comparisons in terms of loss magnitude. This ratio is easy to use, but actually only a part of the property loss (fixed assets and lost inventory) is formally involved in the economic production. In fact, the loss to GNP ratio is used as a proxy. A correct analysis should separate the loss in specific shares and report the lost assets relative to the National Wealth and the lost output of goods and services relative to the GNP. Although it is known that it is not possible to measure the impact of disasters in terms of a single financial figure, World Bank officers consider that any summed losses that are over 2 % of GDP of a country can be destructive or even catastrophic (Gurenko, 2004).

A comparison of losses between Romania and Japan was made in 1992, using some special indices, while another analysis of the 1977 earthquake losses was made with the Global Econometric Scaling using Knowledge on Earthquake Effects; the first estimate of 1977 earthquake resulted in a property loss of 5% of GNP or 1.63% of National Wealth (Georgescu & Kuribayashi, 1992, 1994, 1996, 1998; Georgescu, 2002 a).

Comparatively, in Europe, the ratio of earthquake losses to GNP reached values such as: 15% in Skopje, Yugoslavia, 1963; 1.6% in Friuli, Italy, 1976; 10% in Montenegro, Yugoslavia, 1979 (with reference to all Yugoslavia GNP) or a ratio of 40% of the GNP of Montenegro; 4.44 % Irpinia, Italy, 1980. The peak worldwide values are: 41.50 % in Kanto, Japan, 1923; 45.00 % in Managua, Nicaragua, 1972; 32.16 %-60.00 % in Guatemala, 1976; 25.00 % in El Salvador, 1986.

Romania's losses in 1977 were presumably underestimated by comparison to the scale of damages in other countries, as for instance, the 1963 Skopje and 1979 Montenegro earthquakes in Yugoslavia and the comparison shows that:

- the ratio of 15% loss after the Skopje, 1963 disaster highlights how the size of loss increases when the capital city of small countries is directly affected; the economic weight of Bucharest in the entire economy in 1977 was over 10% (Georgescu and Sandi, 1998, 2000);
- the ratio of 10% loss to GNP after the Montenegro, 1979 disaster applied to the GNP data of Yugoslavia leads to a loss of some US$ 6.3 billion. Since the affected area and number of damaged elements in Montenegro were clearly below the extent of those in Romania, the 1977 losses can be considered as undervalued. It is possible that the unit costs used in Yugoslavia were higher and closer to international prices. The extent of World Bank Projects in Montenegro for rehabili-tation purposes reached some US$ 125 million.

A recent regional earthquake that has some similar patterns with Romanian earthquake of 1977, in terms of magnitude and large affected area, number of damaged buildings and affected industry, was the 17 August 1999, Izmit, Turkey earthquake. Initial loss estimates for this event are in the range of 3 to 6.5 billion US$ (equivalent to some 1.5-3.3% of Turkey's 1999 GNP). Significant economic impacts and fiscal burdens were evaluated by the World Bank (World Bank, 1999). The November 12, 1999 Duzce aftershock added to the damage.

Erdik (2000, 2002) published data on impact and evaluated the average total loss (physical and socio-economic) to be in the range of US$ 16 to 20 billion, about 7-10% of the Turkey's GDP, out

of which physical losses were between US$ 4 to 10 billion. Akgiray, Barbarosoglu and Erdik, 2003, estimated for OECD that the accumulated cost in terms of both income loss and national wealth loss is in the range from US$ 9 to 13 billion according to the State Planning Organization and from US$ 6 to 10 billion according to the World Bank, up to more than US$ 15 billion (TUSAID). Considering the indirect and long-term effects, they believed that it would not be unrealistic to estimate the total cost at around US$ 20 billion, about 9-10% of the GDP in the year of 2000.

The Athens, Mount Parnitha, Greece earthquake of 7 September 1999, the costliest natural disaster in Greece's recent history, is also comparable with Romania 1977 at least in terms of some elements at risk affected but not as area. The total cost was estimated at 3.77 billion Euro; adding insured losses and other losses that may not be accounted for, early estimates warned that the total cost may approach or even exceed 4 billion Euro (around 3% of Greece's GDP in 1999; Pomonis, 2002).

If Turkish losses are theoretically discounted for 1977, they compare well with the Romanian losses. If Greek loss ratio is considered, the loss ratio of Romania is well below a reasonable weight. In the Athens 1999 earthquake for which the dwelling damage data and loss estimations are quite accurate there were 217,940 affected dwelling units which is equivalent to 3.8% of Greece's dwelling stock at the time of the earthquake (as opposed to around 12.5% of the Romanian dwelling stock being affected during the 1977 earthquake). Of the affected units, 3.0% collapsed or would be demolished (0.11% of the total dwellings in Greece, while in 1977 in Romania around 0.6% of the country's dwellings collapsed or were subsequently demolished).

Thus, we have numerous reasons to look for a greater loss ratio after March 4, 1977 and in order to re-evaluate loss to GNP ratio of Romania, both terms of equation must be re-evaluated using new data.

3. THE 1977 EARTHQUAKE LOSSES AND THEIR IMPACT ON DEVELOPMENT

Based on recovered data, the impact of the March 4, 1977 earthquake was re-evaluated as follows (Georgescu and Pomonis, 2007, 2008):

- in visible, direct and indirect terms: the social and economic impact of the earthquake weakened an economy that for several years before 1977 was considered the fastest growing among the East European Countries, the Romanian economy started to slow down from 1980 and eventually collapsed a decade after 1977;
- in latent terms: hidden, neglected or un-repaired damage to thousands of large residential buildings, can become the root for future damage and hardship.

On the other hand, the 1977 earthquake provided a great scientific laboratory (Sandi 1982, 1984, 1985, 1986. 1999), unique and valuable lessons in seismological and engineering terms, as it led to a change in concepts and regulations, analyzed elsewhere (Georgescu, 2002 b).

As measures taken to cope with the disaster, the contemporary data indicate that:

- the situation was under control, there was no food or water shortage, epidemics were absent and rescue operations pace was fast; electricity, telephone, radio and television broadcasts have resumed within few hours; transportation networks were operational; rescue operations started within hours, citizens volunteered for aid;
- on a short-term, the provisional shelters were necessary only in some localities, because the ongoing public investment in urban housing allowed the government to provide housing, furniture and goods for the rescued and the homeless from state funds.

The great extent of physical damage cannot be denied and figures of the World Bank Report and ICCPDC Reports stand as proof. Under a system

of compulsory insurance and controlled use of money, the paid losses reached Romanian Lei 1.01 billion with the 1977 loss ratio (paid claims over premium income) reaching 250% (Ciurel, 1997).

The Romanian authorities' strategy was to keep the Five Year Plan development targets while starting immediately an ambitious reconstruction program as communicated to the World Bank (World Bank Report, 1978). As loss affected mainly buildings and infrastructure works, a strong construction sector and material resources were necessary for recovery.

Thus, while asking for loans for post-earthquake recovery, the main targets were constructions for industrial development and a declared important issue was to accelerate the capacity of the construction sector and contributing sub-sectors. A US$ 60 million credit by the World Bank was negotiated for 1977-1982. In order to cope with immediate needs, some planned infrastructure projects were deferred and resources diverted from other sectors. The need for the import of construction materials was urgent, while exports were reduced and the international borrowing increased.

Strengthening of damaged residential buildings was rarely achieved and it was not considered to be a priority; we know that in this respect "orders" were given in the summer of 1977 to reduce the amount of strengthening so as to become merely local repairs. Only in this way could the rehabilitation works be finished by the end of 1978, as declared.

During 1977, social solidarity was a real fact, but some "measures" obliged the population to work "voluntarily" on all Sundays in March 1977, for two Sundays in April and May 1977 and one Sunday during the remaining months of 1977. Other "voluntary" assistance on reconstruction sites was asked from staff and students. Construction engineers and workers were taken from other less-damaged or non-affected zones, while army staff was used also. The reduced work week was postponed for two years.

In respect of growth and development issues, contemporary documents and other more recent ones stressed-out that:

- for a long time before the 1977 earthquake, Romania was a fast growing centrally planned economy, with an average annual growth of national income of 10% for 1950-1977; in some comparative studies, Romania's industrial manufacturing export policy was considered a source of growth since 1965, with growth rates of 11.2% for 1970-1975, neglecting agricultural exports (Burakow, 1980);
- Romania had the highest average annual growth per capita GDP of 8.5% for 1960-1977 out of 125 countries surveyed (World Bank, 1979), or even a 14.5% growth of industrial output, the highest in Eastern Europe (Encyclopedia Americana. Intl. Ed., 1970);
- Romania used in 1971-75 a ratio of 34.1% of GNP for development, 50% of investment accounted for industry (60% of GNP and 40% of labor force);
- in 1976, foreign trade exports exceeded imports for first time (US$ 3,403 million);
- in 1976 the costliest development project of Romania was restarted, the Danube-Black Sea Navigation Canal, which was partially completed in 1984;
- the "success-story" Romania at that time was relying on its privileged relationships with Western economies, unique membership among CMEA countries of IMF, IBRD – World Bank, and it was a matter of national pride to continue development as planned;
- the construction sector was critical in this process and we must evaluate it in the framework of the situation of that age. Its performance in the years before the earthquake was considered disappointing, as the 1976 investments plan was only half fulfilled (World Bank, 1978);
- it is symptomatic that the official domestic development strategies did not consider the earthquake impact as a threat, since Romania estimated in 1979 that it would be able to reach by 1985 a stage of medium development (citation in Burakow, 1980);
- World Bank analysts have shown acceptance of domestic data and an optimistic view on the continuation of the highest growth rates in the 1980's and the achievements of the development targets

(Tsantis and Pepper, 1979); however other analysts (Jackson, 1977, cited in Burakow, 1980; Jackson, 1985) critically evaluated a series of data and concluded that the development resources would be exhausted in the 1980's and such growth rates were upwards biased;

- in contradiction with its usual trend of upwards bias in estimations on communist economies, CIA data of 1986 reported real GNP growth rates for Romania as of only 6.7% for 1971-75 and 3.9 % for 1976-80 (CIA, 1986);
- later-on, Lancieri, 1993, re-evaluating the GNP and growth of East European economies, put forward the hypothesis that their technological and organi-zational evolution basically stopped in the early 1970's.

With regard to the foreign debt issues, the World Bank data and other recently available studies (Deletant, 2002, Deletant and Ionescu, 2004, Georgescu and Pomonis, 2007, 2008), stressed-out that:

- the international context of energy market prices was already unfavorable; the domestic refining capacities required crude oil import and the 1978 revolution in Iran cut affordable import sources;
- after the floods of 1970-1975 in Romania, foreign credits were taken; in June 1977 the medium and long-term external debt reached US$ 3,266 million, mostly from West European creditors, USA and Japan; not entirely and necessarily related to the earthquake loss, yearly payments were in the range of US$ 700 million in 1978 and 1979, while foreign debts raised to US$ 10.2 billion in 1981 and over US$ 11 billion in 1982, leading to a request of debt payments rescheduling in 1981;
- given that the 1977 earthquake loss possibly had a negative influence on the foreign trade debt balance lasting until 1981, as well as on the construc-tion sector, already overloaded, the solution was a forced reduction of imports and some isolation from the Western economies. The priority given to the machine-construction industry was in some contradiction with what the construction sector could achieve without competitive equipment, although the loans were also for such aims;
- at the end of 1982 the regime leader decided to pay off all debts abroad by 1990. Because of this ambition, a harsh austerity program started, with food rationing between 1982-1983, forced savings of energy, heat supply cuts in 1984-1985;
- unfortunately, the 1977 earthquake was also used as a pretext to launch the "systematization program" first proposed in 1974, which practically was the razing to the ground of urban and rural heritage. The need for repair or strengthening of affected buildings was replaced by hazardous planning decisions, i.e. the demolition of old houses and many villages, although they did not pose any risk for mass casualties. The damaged pre-1940 high-rise buildings were only given a face-lift. Therefore, after 1970's, vital resources were wasted to demolish and then rebuild 29 traditional town centres and to reshape up to mutilation point another 37 cities (the new Civic Center of Bucharest is a well publicized case), while at the same time the most vulnerable buildings that were damaged by the earthquake were left practically untouched (Giurescu, 1989). Turnock (1991) discusses in detail the "systematization program" and its effect on rural settlements in Romania and proposes that the 1977 earthquake may have eventually served as a delaying factor to the completion of the "systematization program" that would have had disastrous consequences for Romanian farmers;
- thus, five years after 1977, under the combined effect of the earthquake, floods, the sudden increase of international interest rates and due to its own economy's systemic weakness (artificial and low-quality production, pumping funds into huge energy

inefficient and loss making chemical and steel processing plants that generated environment pollution problems etc.), Romania was faced with an economic crisis considered by the cited analysts as "deep" and in a "profound stagnation";

- the resilience of the Romanian economy to the impact of the earthquake was of interest even to the KGB, as their high level officials expected harsh conditions and even economic collapse (Andrew and Gordievsky, 1990).

Under the UNO system of national accounts reporting, the usual statistical data can be a reliable source of information on a disaster's impact. In time, some countries presented more unfavorable impacts (sudden decrease in GNP), for instance Japan after 1923, Mexico after 1985 and El Salvador after 1986 earthquakes respectively. Disasters lead also to a "heating" of sectors involved in recovery. These "visible" earthquake effects on economic indicators should be considered with care, since the interference of direct and indirect losses under different circumstances around the world can be misleading.

In case of Romanian statistical economic data before and after 1977, the impact is somehow visible, although it cannot be entirely caused by the earthquake, as follows (Georgescu and Pomonis, 2007, 2008):

- the GNP graph in Figure 2 shows a decline in growth rates; the material product in construction stagnated and then decreased, after 1977 (DCS data in Jackson, 1985); growth rates decreased after 1977 until 1979 for Net Material Product, agriculture and industrial activities, while constructions grew in 1977 but dropped sharply in 1978 and 1979 (UNSY, 1980).

4. HUMAN CASUALTY PATTERNS VS. BUILDING COLLAPSE PATTERN AND SEARCH AND RESCUE NEEDS IN MARCH 4, 1977 EARTHQUAKE

Concerning human-social impact, data from the Bulletin of the Seismological Society of America, BSSA (1978) give an estimation on April 30, 1977 with a 1,578 deaths (1,424 deaths in Bucharest and

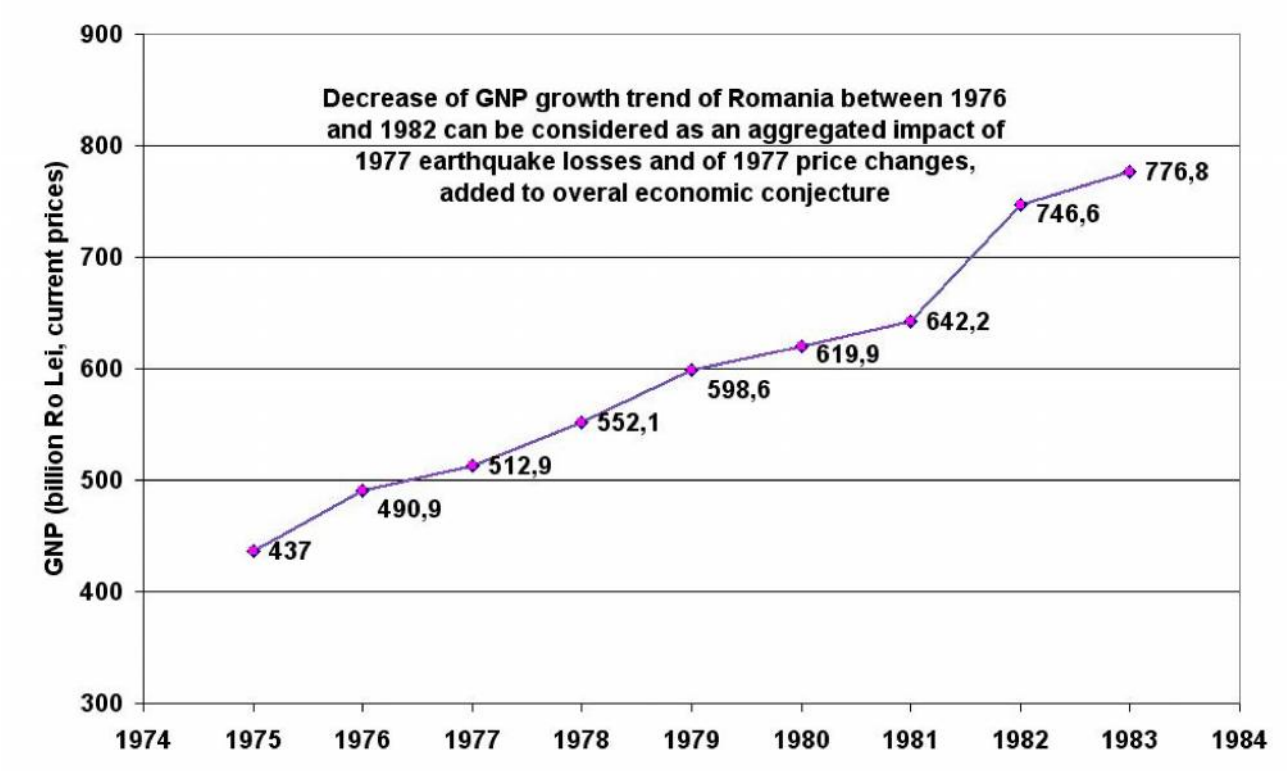

Fig. 2. Romania's GNP evolution (1975-1983) shows some decrease in the growth ratio in 1976-1979, attributable to a certain extent to the 1977 earthquake (data from Romanian sources communicated to World Bank experts, Jackson, 1985)

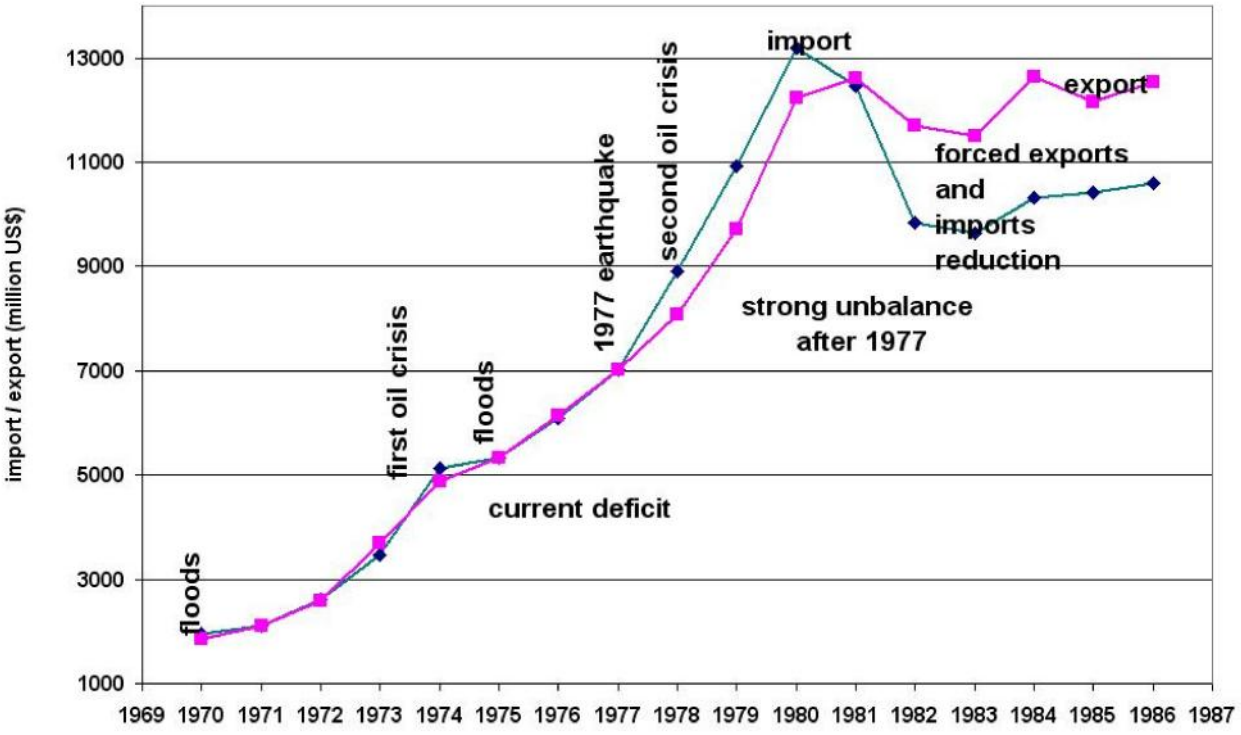

Fig. 3. Romania's foreign trade balance (1970-1986) was influenced by the impact of natural disasters as well as by the international economic situation and political decisions. The visible impact of 1977 earthquake must be considered in conjunction with other factors

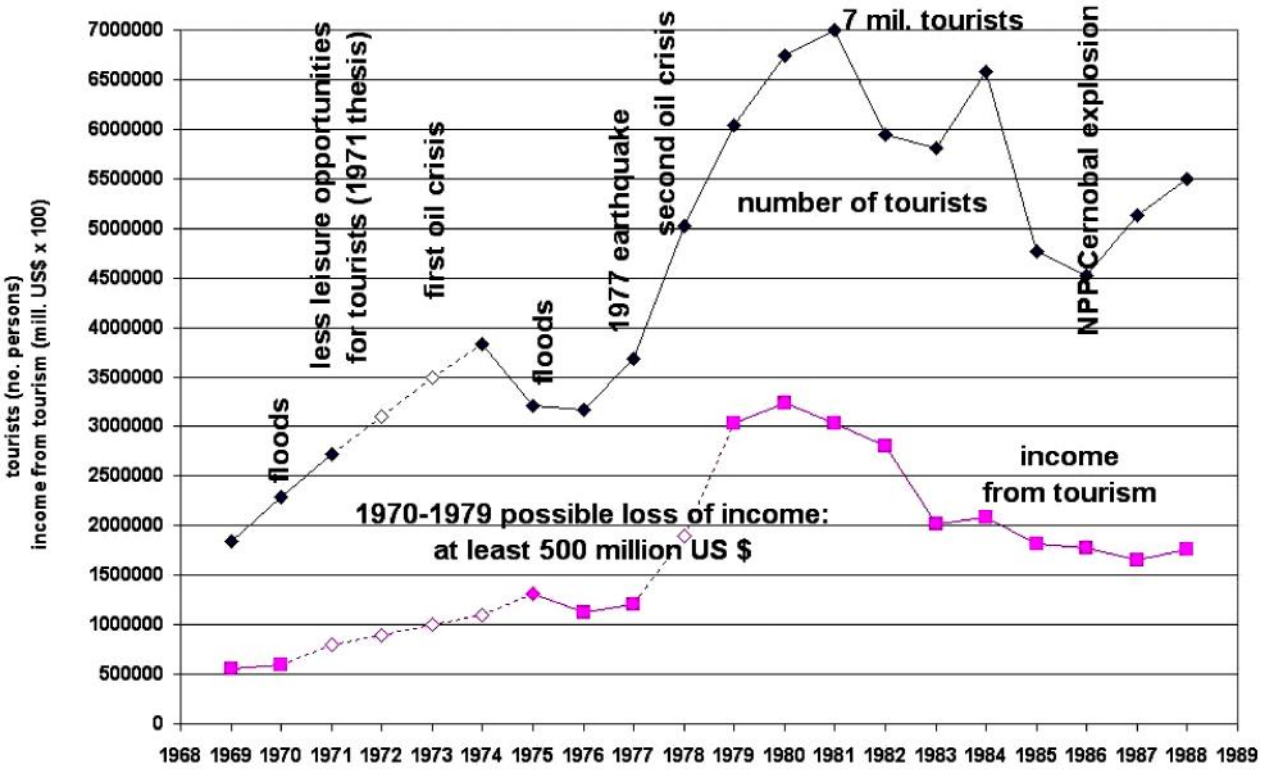

Fig. 4. Inetrnational tourist arrivals and resulting income in Romania (1969-1988) was mainly impacted by the international economic situation and domestic political decisions but natural disasters may have also played a part

154 in the rest of the country), 11,321 injured (7,598 in Bucharest and 3,723 in the rest of the country) and 200,000 homeless. The figure of 1,578 deaths is cited also by US Congress Records, 1977. Other sources give 1,541 deaths and 11,275 injured (out of which 1,200 deaths and 7,576 injured in Bucharest) (Steiner and Manastireanu, 1996).

The overall casualty figures for Romania and Bucharest and spatial distribution of the human casualties are presented in Table 4. Some of the casualty distribution patterns may positively correlate to the damage distribution pattern but not to full extent. In rural areas the damage was not associated with heavy loss of life, e.g. the town of Zimnicea on the Danube was heavily affected but only a handful of deceased persons have been reported (Moinfar, 1978; Tezcan, 1977, Georgescu, 2002 a). The ratio of reported injuries to deaths was 7 (5.3 in Bucharest and 22.9 in the rest of the country) which is equal to the average injury to death ratio experienced in Japan during the period 1946-2006 (Pomonis, 2005).

In the 1977 earthquake, the casualties were concentrated in Bucharest, with 90.2% of the killed and 67.1% of the injured. In Table 5 we summarize the information we have collected so far for each of the 29 collapsed buildings in Bucharest. Due to the time of occurrence (9:21 pm local time) the bulk of the fatalities was due to the total or partial collapse of 23 pre-1940 residential high-rise reinforced concrete frame structures, not designed to withstand earthquakes. These were situated in the city centre and mostly on street corners. Most of these buildings had also been damaged by the 1940 earthquake but had not been strengthened properly (World Bank, 1978). In addition about 150 buildings of this category were seriously damaged and many were subsequently demolished. Furthermore 4 non-residential buildings collapsed (a 4-storey hotel, the Ministry of Metalurgy, the Computer Centre and the Chemistry Faculty building of the University of Bucharest; the latter had been seriously damaged during World War II bombing). There was also the

Table 4.

The spatial distribution of human casualties in Romania due to the Vrancea, March 4, 1977 earthquake (Georgescu and Pomonis, 2010, 2011)

City or County	Killed	Injured	Killed %	Injured %	Hospitalised
Bucharest City	1,424	7,598	90.2%	67.1%	1,500
Craiova City	30	500	1.9%	4.4%	?
rest of Dolj County (excl. Craiova)	11	315...562	0.7%	2.8...5.0%	?
Prahova County	15	?	1.0%	?	?
Vaslui County	7	40	0.4%	0.4%	?
Iasi City	4	270...440	0.3%	2.4...3.9%	?
Zimnicea Town	5	62...600	0.3%	0.5...5.3%	?
Tr. Magurele Town	4	70	0.3%	0.6%	?
Alexandria City	3	?	0.2%	?	?
Vrancea County	2	23	0.1%	0.2%	?
Giurgiu City	1	35	0.1%	0.3%	?
Buzau County	0	55	0.0%	0.5%	?
Other places	72	1,352...2,310	4.6%	11.9...20.4%	(869 in all other counties)
TOTAL					
as of March 14, 1977 domestic newspapers reports	1,541	11,275			2,369
As in BSSA data	1,578	11,321			

partial collapse of 2 residential high-rise reinforced concrete shear wall structures (Block 30 and Block OD16). These had 10 and 11 storeys and were built in 1962 and 1974 respectively. The collapse of these two blocks affected 77 apartment units in total. At the time there existed 185,000 such modern apartment units (all constructed after 1950). In addition there was the collapse of four pre-1940 mid-rise unreinforced brick masonry buildings of 3 to 6 storeys two of which were the aforementioned hotel and Chemistry faculty buildings. The 3-storeyed Computer Centre of the Ministry of Transport and Communi-cations was built in 1968 and was a reinforced concrete waffle slab structure on columns with capitals in the form of truncated square pyramid at ground storey.

The number of people killed and rescued in each of the collapsed buildings is not exactly known, but some data were collected by the authors mainly from survivors' memories and press reports. We identified the collapse patterns by collecting photos and processed casualty and rescue data for some of the 29 collapsed buildings. Pancake collapse pattern was common for the pre-1940 structures, while shear-wall failure and soft-storey were causes for the collapse of the three modern buildings that had lower levels of volume loss. Loss of volume ratio was in the range of 0.15 to 0.85. Some of them fit to loss of volume and casualties ratio in the international literature (e.g. Pomonis et al., 2011; Pomonis et al., 1991).

We estimate that high lethality (> 50%) occurred in the main Bucharest collapse sites as the collapse pattern was quite extreme in most of the pre-1940 residential blocks, and inhabitant's chances of survival would have been diminished by the relatively low tempera-tures during the first and critical night. Causes of deaths and injuries were the crushing under concrete or under members or parts of buildings and falling of non-structural members.

The number of killed, injured and hospitalised in Romania after the March 4, 1977 Vrancea earthquake was preliminarily recovered, mostly from press sources, checked for final values with the BSSA data, and is presented in Figures 5 and 6. Based on these, a distribution of casualties was estimated, for the sum of final numbers of fatalities, light to moderate injuries and victims hospitalized (a total of 12,899 casualties), as represented in Figure 5. We propose a total for the event at 1,700 deaths and 11,500 injured (incl. the casualties that occurred due to building collapse and other causes in Bulgaria and the Republic of Moldova). The 1977 event killed 120 people (Tzenov and Botev, 2009) and injured around 165 in Bulgaria, most of them caused by the collapse of 4 buildings in the town of Svishtov (on the southern shores of the Danube River). It also caused some injuries in Yugoslavia and 2 deaths in the Republic of Moldova.

These data are influenced by the number and patterns of Bucharest casualties, with victims under concrete debris and they are not necessarily simultaneously valid, per each day, as it was a continuous flow of entries and exits from hospitals. To a certain extent, the figures provide also an image about the speed of extrication as well as about the ratios between killed and injured. The pattern of injuries was reported by Steiner and Manastireanu (1996) for 6,980 patients, and some 49.7% were treated for surgical and orthopaedic wounds. More details about the geographic distribution of the casualties including those outside Romania during the 1977 earthquake are given in Georgescu and Pomonis (2010).

Search and rescue needs were extensive as 23 of the 29 collapsed buildings were heavily occupied residential structures with 15 to 89 apartments in each and extrication of the trapped was very difficult. Fire occurred after collapse in several cases. As a result of intensive work, the emergency state was ceased on March 10, 1977 in the country, but in Bucharest it continued for many more days (e.g. Boulevard Magheru, the main traffic artery in the city centre was closed for more than a week).

5. CONCLUSIONS AND LESSONS FOR SEISMIC RISK REDUCTION STRATEGIES

5.1. Physical and economic losses of 1977 vs. territorial distribution and hidden damage threat

The loss and impact data proves that the 1977 earthquake was a disaster of great consequences that affected numerous citizens, destroyed and damaged a significant proportion of the residential

Table 5.

List of the 29 buildings that collapsed in Bucharest during the March 4, 1977 earthquake, in correlation with emergency management issues (partial data from unofficial sources) (Georgescu and Pomonis, 2010, 2011)

BUILDING NAME AND ADDRESS	YEAR BUILT	STRUCTURE, NO. OF FLOORS AND COLLAPSE TYPE	CASUALTIES DATA
Bloc Casata, Bd. Magheru 26	1937	RC Fr/ 11/partial	
Bloc Lido, Str. An. Simu 6 (Franklin 11)	1905	RC Fr/8/partial	
Bloc Scala, Bd. Balcescu 36	1937	RC Fr/ 11/total	108 corpses pulled out by March 6; 8 rescued (1 woman working in the basement kitchen that survived under a metal desk; 1 woman under a door frame; 1 man around 80+ hrs later)
Bloc Wilson, Bd. Balcescu 25	1940	RC Fr/11/partial	3 rescued circa 13 hrs. later (cuting steel, opening a hole)
Bloc Dunarea, Bd. Balcescu 3-5	1940	RC Fr/ 9/partial	
Bloc Continental, Colonadelor 3	1935	RC Fr/11/ total	300 deaths said by Poetess Ana Blandiana on March 4, 2010 *; a girl of 6.5 yrs old rescued around 61-72 hrs later, mother alive, 2 brothers killed; lawyer rescued 110 hrs later; 19 yr old boy rescued in basement 251 hrs later
Str. Bibliotecii 6	1939	RC Fr/ 11/total	* Casualties may have been accounted together for these 2 neighboring buildings
Bloc Nestor, Calea Victoriei 63-69	1937	RC Fr/9/partial	4 rescued from basement? after 45 hrs
Str. Pictor Grigorescu 2 Pasaj Comedia	Ca. 1930	RC Fr/9/partial URM/6/total	
Academiei 5 Ministry Offices	1936	RC Fr/10/partial	
Bloc Belvedere, Str. Brezoianu 7	1938	RC Fr/ 14/total	Fire followed; 4 rescued (by March 7) 2 were women
Hotel Victoria, Str. Lipscani	Before 1900	URM/4/partial	
Str. Poenaru Bordea 18	Ca. 1930	RC Fr/8/partial	
Str. Poenaru Bordea 20	Ca. 1930	RC Fr/8/total	
Str. Apolodor 31		RC Fr/9/partial	
Str. Scoalei 2	1937	RC Fr/8/partial	
Str. Alex. Sahia 58 (J.L. Calderon)	1935	RC Fr/9/total	Woman rescued 197 hrs later
Str. Galati 33 (Vas. Lascar)	1936	RC Fr/7/partial	
Str. Popa Rusu 11	1932	URM/3/ total	
Str. Alex. Sahia 1-3 (J.L. Calderon)	1938	RC F/10/ total	Fire followed; 25 killed & 4 rescued (by March 7)
Str. Tudor Arghezi 1	1938	RC Fr/9/ total	A student rescued after 62 hours, a 22 yrs. woman that was at 7-th floor rescued after 127 hours, found at basement level
Str. Hristo Botev 10	Ca. 1930	RC Fr/10/ total	107 dead recovered, testimony of Gh. Florescu, 2011
Str. Lipscani 102	1927	URM/ 6/total	
Calea Mosilor 132	1937	RC Fr/ 11/total	
Bloc 30, Soseaua Stefan cel Mare 33	1962	RC SW/10/partial	16 tenants dead and 1 visitor; 1 person dead outside (survivor s testimony, 2009)
Bloc OD 16, Bd. Pacii 7	1974	RC SW/11/total	3 rescued injured immediately; 26 corpses were recovered by noon of March 5
Comp. Center, Str. Garii de Nord	1968	RC SW + Fr/3/total	
Fac.Chemistry, Splaiul Independentei 87	<1940	URM/5/partial	Damaged by bombing in WW2 (1944) and rebuilt; fire followed in 1977

Notes: *RC-reinforced concrete; Fr- Frames; URM-Unreinforced Masonry; SW-Shear Walls*

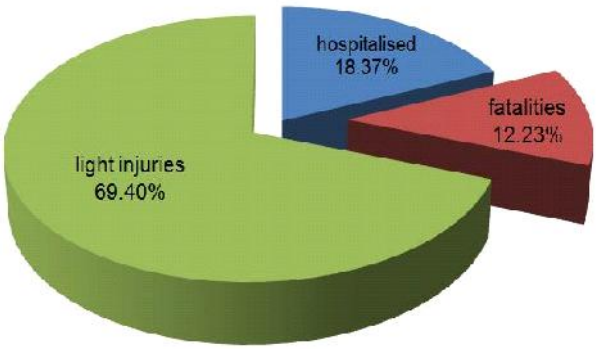

Fig. 5. Estimated distribution of casualties in 1977 earthquake, in Romania

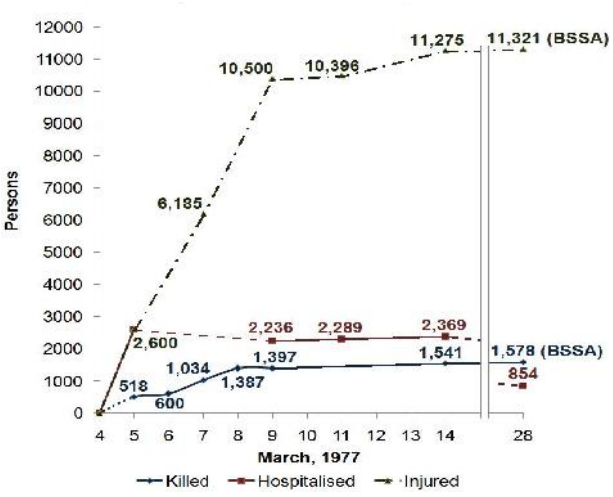

Fig. 6. The number of killed, injured and hospitalised after March 4, 1977 Vrancea earthquake, in Romania

and non-residential building stock of Romania and affected a large portion of Romania, adding strain to the economy and its future prospects. This disaster concurred with the 1970's Romanian floods to contribute towards the very difficult economic and social situation of the 1980's in Romania. Some negative impact was immediately visible, while other had a period of "incubation", depending on internal and international situation. In this respect, World Bank analysts considered that an improved efficiency of the Romanian economy was highly necessary. They also mentioned that "the bulk of the burden of recovery has been borne by the Romanian population with some external rehabilitation assistance" (World Bank Report, 1978).

The term of "ambivalence and ambi-guities" used by Deletant, 2002 for Romanian politics under the Warsaw Pact, could possibly be true for the attitude on earthquake risk reduction as well. Immediately after the earthquake, contacts with all foreign visiting experts and consultants were quite free and the opening towards the international scientific community was extremely beneficial for Romanian researchers.

The 1977 earthquake provided a great scientific laboratory, based on unique and valuable lessons in seismological and engineering terms and led to a change in concepts and regulations. Two projects on seismic risk financed by United Nations agencies started in the region, with evalu-ations, case studies, seminars and fellowships. But although professional institutions and the Romanian Association of Civil Engineers promoted activities and regulations in order to mitigate the earthquake risk, the official actions were mostly concerned with other development projects and neglected the potential for disaster from future earthquakes.

In fact, for more than a decade (1977-1989) the large-scale works needed for the seismic risk reduction of existing buildings were subject to a stalemate. There is a striking difference between the huge damage caused to 20 counties and the subsequent funds allocated to rehabilitation and strengthening. In the summer of 1977 public policies enforced the rule of limited repair and strengthening by local interventions for cosmetic purposes to "reach the pre-earthquake safety level".

Unfortunately, the use of local resources prevailed over other needs, therefore the USA funds and World Bank credits for a National Center for Earthquake Engineering at INCERC were replaced with local currency funds and „costly" imported equipment was replaced by "alternative" local solutions. This idea caused the Center completion to be delayed for years and the shaking-tables eventually failed to be equipped. The same delay happened with the equipments of the Computing Center of the Ministry of Transportation that collapsed in the earthquake (World Bank, 1983). The 1983 World Bank report evaluating the post-earthquake loan to Romania stated that "it had a major positive impact on Romania's economic performance during the 1976-1980 Five Year Plan and thereafter, fulfilled the tasks of reconstruction and strengthening the construction sector and

building materials, with a high growth, while failing to limit the damage from future earthquakes through the National Earthquake Protection Plan".

The re-evaluation of past earthquake losses requires access to more data and archives which with time will provide new insights. The re-evaluation of loss to GNP ratio, as well as other specific studies, can provide a clearer picture of what happened, but is still dependent on a better estimation of Romania's true GNP at that time.

According to current estimations, we have reached a new insight on losses and the range of direct loss to GDP or GNP ratio in 1977 could have been from 4.9 to 7.8%, while the range of total loss to GDP or GNP ratio in 1977 could have been from 6.0% to 9.5%. Adding further indirect losses that were unaccounted at the time brings the range of total possible loss ratio to GDP or GNP in 1977 to between 13.3% and 21.1%. Such values are considerably closer to the strong negative impact that was felt by the entire economy and society for more that a decade, until the political system's collapse in late 1989 and later on. They also better compare to losses of other countries in the southeast of Europe (Italy, ex-Yugoslavia, Turkey and Greece).

The impact of the 1977 earthquake is still a threat to Romania's future development prospects. We know that there are hidden, neglected or un-repaired damages which represent the roots of future cumulative structural vulnerability, a bitter heritage from 1977 for today's society, which may possibly suffer and pay for another earthquake disaster in years to come. We consider that the re-evaluation of the 1977 earthquake's socio-economic consequences, must be the benchmark for a new strategy on seismic risk reduction in Romania which if successful would prevent further large scale impacts. The recurrence cycle of great Vrancea earthquakes represents a warning. In this context, Romania's EU integration and the new Romanian Earthquake Design Codes based on Eurocode requirements on earthquake recurrence intervals of 100 and 475 years return period must be tackled with due concern.

5.2. Human casualties pattern vs. collapse pattern and territorial distribution

The study recovered and interpreted data about the human casualties caused by the 1977 earthquake. The data show that some towns and counties located at large distances from the Vrancea source zone suffered heavy damage and some casualties in 1977, but the cumulative damage effects, especially to pre-1940 high-rise buildings, explains the concentration of losses and casualties in Bucharest.

In terms of preparedness for future Vrancea earthquakes the data recovered and interpreted about human casualties and search and rescue operations after the 1977 earthquake, were primarily related to the collapse of 23 pre-1940 high-rise apartment buildings, especially in Bucharest. Other pre-1977 low-code buildings, with soft-story weaknesses and low-ductility are also a threat and may collapse causing further casualties (though these have a much lower collapse probability). The stock of low-rise and mid-rise old masonry buildings is still numerous in rural Romania and smaller towns in Vrancea, Muntenia and Moldova regions, but their casualty potential is not as great, though it can be a burden for health and financial assis-tance. Ratios of injured to killed in overall casualties in Romania was 7.17 in 1977 and 5.33 in Bucharest.

In 1978 a new earthquake code was introduced and subsequently upgraded in 1992 and 2006, significantly reducing the seismic resistance of buildings and their probability of collapse. However, structural alterations and aging of pre-1977 buildings is an additional concern.

We are concerned that there remain at least 100 and perhaps as many as 250 collapse candidate buildings in Bucharest and other cities of south-eastern and north-eastern Romania, many of which have been damaged by the 1940, 1977, 1986 and 1990 Vrancea earthquakes. Buildings in this category have been registered and signposted by the authorities in Bucharest and other cities but only about around 20 have been strengthened so far. Many of these are multi-storey, high occupancy buildings and can be a great risk to life in case of partial or total collapse. Search and rescue in case of tall building collapse is a very difficult task and requires extremely rapid mobilization and heavy equipment in many locations.

As a strategic thinking for emergency management, the following measures are of utmost importance and will have the greatest mitigation potential:

- strengthening that prevents the potential collapse of the already identified "high-risk" structures, incl. weak-story or overturning effects; this measure would considerably mitigate potential deaths and injuries from Vrancea earthquakes in Bucharest and other cities;
- publicly-funded subsidies incl. funds for interim relocation housing during the strengthening or demolition and replacement of the "high-risk" buildings;
- prevention of wall and roof collapse in rural weak masonry buildings, by introduction of collar beams;
- training for search and rescue in specific collapse patterns, using advanced instruments for victims detection and equipment for speedy extrication.

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