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Study on seismic losses distribution in Romania and Japan

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ABSTRACT: The paper presents the analysis and comparison of the scale and distribution of earthquake losses in Romania and Japan, using specific engineering and economic indexes and methods (Kuribayashi et al. 1991, 1985, 1978), in order to provide adequate strategy and tactics for earthquake disasters prevention programs (Kuribayashi 1991, Georgescu 1986.)

1. INTRODUCTION

For a long period, the study of seismic losses has been concentrated mostly on engineering aspects. Nevertheless, during the past two decades has been remarked a trend towards an interdisciplinary socio-economic approach of earthquake losses study. (Kuribayashi et al. 1991, 1980, 1978.)

Romania suffered heavy damage and losses as a consequence of the 1940 and 1977 Vrancea earthquakes. The unique pattern of its earthquakes are the depths of 100km and affected area on more than 100,000 sq. km, the peculiar distribution pattern of intensities and losses, with low attenuation and amplifications at some 200-300 km of epicentral area. (Enescu, Radu, 1982.)

Japan underwent numerous earthquakes in the last 100 years, with a clear evolution from heavy losses to manageable ones. Both countries suffered from the damaging earthquakes in the 1968-1978 decade, when acquiring high economic growth rates. This is the first attempt to compare the long term effects of earthquakes in Romania and Japan.

2. METHODS OF STUDY

The econometric modelling and study of earthquake losses has been reported elsewhere (Kuribayashi et al. 1978, 1980, 1985) and briefly includes:
- the indexes for property loss of different facilities, areas or countries;
- the correlation of seismological and geological data with existing assets and past losses size, in order to derive the size and distribution of future losses;
- the direct loss model (physical losses);
- the indirect loss model (mid-term and long-term economic effects, using simulations and input-output analysis).

The authors reviewed the existing methods and the available data, essentially for:
- using Japanese methods with the Romanian data, and the Japanese data for calibration or checking of the results;
- developing some simplified methods of loss analysis for the circumstances when there is a lack of losses data;
- making available such methods for countries with no recent experience for disaster prevention programs.

The Romanian research made available:
- a methodology for seismic risk and structural vulnerability analysis (Sandi 1984);
- statistical analysis of earthquakes effects on buildings and inhabitants (Georgescu 1984);
- data about the Romanian earthquakes (Enescu 1982, Radu 1982, Pacoste and Sandi 1991).

3. SEISMIC HAZARD AND PAST DISASTERS

3.1. Romania

The seismicity of Romania is dominated by the intermediate depth source located in Vrancea zone, at the curvature of Carpathian Mountains, roughly identifiable between the parallels of 45° and 46° N and the meridians of 26° and 27° E; a subduction process is supposed to be in development beneath. The 1940 earthquake (M=7.4) and the 1977, March 4 earthquake (M=7.2) are the main seismic disasters of the modern times. The maximum possible magnitude was assessed as 7.5. In 1977 a foreshock and three main shocks were instrumentally identified (Enescu 1982, Radu 1982, Sandi 1991), as presented in the figure 1. The disaster effect of the earthquake was represented by 1,570 deaths, 11,300 injured persons (90% of casualties in Bucharest), 32.900 collapsed or heavy damaged dwellings and other large loss and disruption in densely populated areas of S-E where is living half of the population (World Bank 1978, Balan, St. 1982).

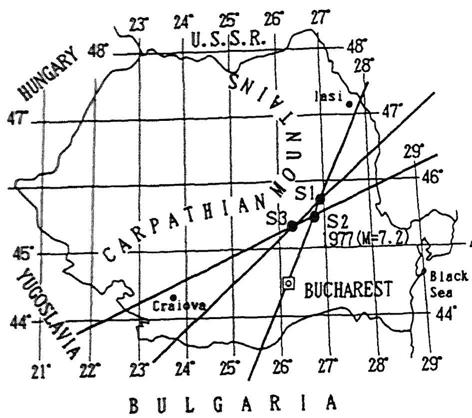

Fig. 1 The map of Romania with the location of the main shocks epicenters of 1977 March 4 earthquake.

3.2 Japan

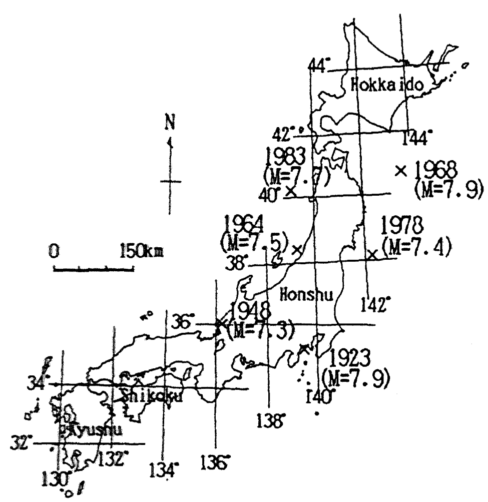

Fig. 2 The map of Japan with the location of the selected earthquakes for loss study.

The seismicity of Japan is strongly marked by the subduction of the Pacific Ocean Plate, Philippine Plate and the deep sea trench along the Eastern side of Nippon Archipelago. The strongly damaging earthquakes of Kanto (1923), Fukui (1948), Niigata (1964), Tokachi-oki (1968), Miyagiken-oki (1978), Nihonkai-chubu (1983) are depicted in the map from the figure 2 with the location and magnitudes.

4. RESULTS

4.1. Macroeconomic damage and loss analysis

The direct damage and loss produced by the Vrancea, Romania, March 4, 1977 Earthquake is presented in the table 1 (World Bank Reports 1978, 1983, Tsantis and Pepper 1979):

Table 1. The March 4, 1977 Romania direct earthquake damage and loss

Damaged assets, lost inventory	Total value (million US$)
Construction (buildings, water supply etc.)	1,420.1
Equipment, installations and transport	104.3
Raw materials, intermediate products and consumer goods	158.9
Total	1,683.3

This damage has been shared between different economic and social sectors as follows (table 2)

Table 2. The March 4, 1977 Romania direct earthquake damage and loss by sectors

Economic and social sector	Total damage or loss (million US$)
Industry	151.1
Agriculture	74.1
Transport, communications and retail trade	81.2
Health, education and social-cultural	165.6
Housing	1,032.8
Local industry, utilities and construction	83.1
Miscellaneous private goods	95.4
Total	1,683.3

Besides those direct losses, other economic consequences were assessed as indirect (long-term) losses, as in the table 3.

From the tables 1 and 3, the ratio of indirect to direct damage results as 1.7. The comparisons with the basic economic annual figures of Romania in the respective fields in 1977 gives:
- lost production represents a ratio of 1.07% of GNP;

- lost exports represent a ratio of 1.67% of the sum of 1977 and 1978 exports;
- supplementary imports represent a ratio of 4.86% of the 1977 imports;
- tourism receipts loss represent a ratio of 25% of the 1977 achieved value.

Table 3. The March 4, 1977 Romania earthquake indirect losses

Indirect loss item	Total value (million us$)
Production losses	364.7
Lost export contracts over two years	250.0
Supplementary imports for lost equipment replacement	350.0
Tourism receipts loss in 1977	30.0
Loans and credits on, variable terms	180.3
Unpaid work for recovery	1,000.0
Self-made repair works in households	675.0
Total	2,850.0

Table 4. The ratio of damaged assets, lost inventory and production losses within the sectors, due to the March 4, 1977 Romanian earthquake.

Economic and social sector (loss in mill. US$)	Constr. %	Equipm. %	Materials, products goods %	Production losses %
Industry (447.3=100%)	22.96	4.47	6.35	66.22
Agriculture (124.4=100%)	37.30	8.60	13.67	40.43
Transport, communication retail trade (93.2=100%)	55.90	15.45	15.77	12.88
Health, education and social-cultural (167.3=100%)	88.16	10.82	-	1.02
Housing (1,032.8=100%)	98.28	1.72	-	-
Local industry, utilities and construction (87.6=100%)	64.38	26.60	3.88	5.14
Miscellaneous private goods (95.4=100%)	-	-	100.00	-
Total (2,048.0=100%)	69.34	5.09	7.76	17.81

The comparative assessment of selected Japanese earthquakes gives the following ratios of indirect to direct loss:
- for the Miyagi-ken-oki earthquake of 1978, 0.12 for gas utilities, 0.352 for electric power, 0.237 for water supply and 0.02 for the Sendai City revenues. (Kuribayashi 1982)
- for the Nihonkai-chubu earthquake of 1983, a 2.5 times ratio (Kawashima 1990).

The ratio of damage within the sectors is given in the table 4, and consequently the shifting from direct to indirect loss predominance in the industry is visible.

In global terms, the comparison of property losses to GNP and National Wealth is presented in the table 5.

Table 5. Macroeconomic loss indexes derived from economic statistics and seismic damage data in Japan and Romania for selected earthquakes

Earthquake, country, date	Magnit. M (Richter)	Property loss / GNP	Property loss / National Wealth
Kanto, JAPAN 1923, Sept. 1	7.9	41.50%	7.15%
Fukui, JAPAN 1948, June 28	7.3	15.56%	2.74%
Niigata, JAPAN 1964, June 16	7.5	0.70%	0.193%
Tokachi-oki, JAPAN 1968, May 16	7.9	0.11%	0.033%
Miyagiken-oki, JAPAN 1978, June 12	7.4	0.13%	0.041%
Nihonkai-chubu, JAPAN 1983, May 26	7.7	0.052%	0.017%
Vrancea, ROMANIA 1977, March 4	7.2	5.00%	1.63 %

4.2 Individual loss ratio for different facilities

The money value of material damage caused by earthquake in Japan and Romania has been expressed as an index, following the method described by Kuribayashi et al. 1978, 1980, 1991.

The index is given by the equation 1:

$$\text{Individual loss ratio} = \frac{L_k P}{W_k P_D} \cdots\cdots\cdots\cdots (1)$$

L_k: loss valued in money for assets of the facility k
W_k: money value of the existing assets of the facility k
P : country population
P_D: damaged area population

Using the equation 1 the loss ratio has been compared to the loss ratio of property loss and to the range of loss indexes for Japanese earthquakes between 1962 to 1975 and to the 1977 Romania earthquake, as plotted in the figure 3

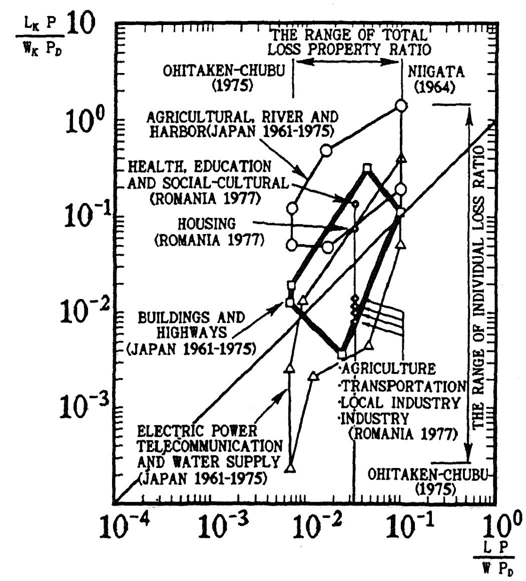

Fig. 3. Comparison of loss ratio indexes for different earthquakes and facilities in Romania and Japan.

From the figure 3 one can remark that Romanian losses are generally of the same order with the Japanese ones, in the zone of loss for buildings and highways. In the same time, the facilities for health, education, social-cultural and housing have an index of loss by 9-17 times higher than the agricultural transportation, communication, retail and industry facilities. The Japanese loss ratios for building and highway facilities are almost of the same degree, and close to the loss ratio of the total loss. In contrast to this, and to the Romanian data, the loss ratio of agriculture, flood control, river and harbor facilities have a greater value than the loss ratio of total loss. The loss ratios of electrical power, telecommunication and water supply facilities are less than the total loss ratio. The individual loss ratio range of facilities in Japan is much larger than the total loss range, fact explained by the variety of facilities, seismic and site conditions and aseismic design provided for them, the trend of the most modern and engineered being to be closer to loss ratio of total loss or smaller.

However, the loss ratios of life-line facilities have a tendency to became closer to that of the total loss when the size of loss increases (Kuribayashi et al. 1991.)

5. TERRITORIAL DISTRIBUTION OF LOSSES

Taking into account the scarcity of Romanian data concerning the distribution of monetary loss on the territory, the authors proceeded as follows:
- the data were processed as damage degree histograms;
- the mean value of damage in each county was represented on profile lines, following those given by the main shocks S_1, S_2, S_3 (Enescu 1982, Radu 1982) as in the figure 1.
- some transversal profiles were also considered.

An example of the mean value of damage degree along a profile is presented in the figure 4

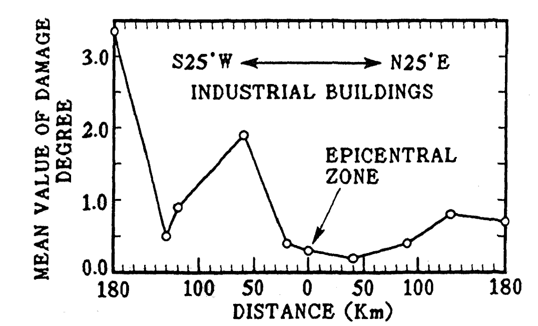

Fig. 4. The distribution of mean value of damage degree along a profile passing through Vrancea zone.

Consequently, the following conclusions can be presented:
- there is a strong amplification from the epicentral area towards the NE and SE;
- the amplification towards the South is generally higher sudden peaks at some mid-distance (Prahova, Bucharest);
- on the perpendicular profiles there are amplifications, from the Carpathian Mountains towards the East and South;
- the profiles through S_3 seems to present

higher amplifications of damage, since the S_3 was the last and strongest shock.

Kagami, Ohashi Murakami, Okada and Ohta (1988) remarked a pattern somewhat similar, in the damage from Nihonkai-chubu earthquake of 1983.

6. THE MODELLING OF LOSSES

6.1. The direct loss model

The Japanese models were adapted to fit the Romanian earthquakes pattern . The physical losses are determined from earthquake intensities and stock of assets. (Kuribayashi 1985). The present zoning maps in Romania provides the seismic intensities (MSK), the seismic design coefficients and three soil categories. The analysis will be performed on a mesh at an adequate scale to consider the change of ground conditions.

The first case is as in the equation 2:

$$Li=f(SA, T, Ki) \quad \cdots\cdots (2)$$

where

Li:loss of the i-th assets in monetary value

SA:Acceleration response spectral value (in gal) for the given fundamental period of the analysed facility, when such data are available

T:fundamental natural period of the facility (sec)

Ki:stock of i-th asset or other substituting index, in monetary value

The second formula is given by the equation 3.

$$Li=f(DD, Ki) \quad \cdots\cdots (3)$$

where

Li:loss of the i-th assets in monetary value

DD:damage degree expressed as a histogram of losses conditioned by an assumed seismic intensity

Ki:stock of i-th asset of other substituting index, in monetary value

As for the whole area supposed to be a support for damage and economic loss, the Japanese data (Kuribayashi 1978) were adapted for Romania as in the equations 4 and 5:

$$\log R1 = 0.545M-1.5 \quad \cdots\cdots (4)$$

$$\log R2 = 0.520M-1.5 \quad \cdots\cdots (5)$$

- R1 and R2, the radiuses defining an ellipse centered on the presented profiles;
- M the magnitude of the earthquake assumed in the loss modelling.

6.2. The indirect loss model

For the Romanian earthquake, the earthquake loss was assessed as follows:

- the incremental capital to output ratio (ICOR) for Romania was considered;
- the loss of fixed assets influence on the output was calculated.

The evaluation using the ICOR for Romania provided an output loss with 10% higher than the official estimation.

For Japan, the secondary and tertiary effects were more significant than the direct ones, but gradually became controlable by the affected economic sectors.

7. CONCLUSIONS

Using the Japanese research methods for the earthquake direct and indirect loss, and statistical data, the study provided a new view on to the econometry of disasters in Romania and Japan.

The comparison of the economic impact proved some early assumptions about the opposite correlation of the loss to the development.

The study quantified the main characteristics of distribution of seismic losses in Romania and Japan:

- in Romania the large area affected and the amplification of the intensities at longer distances, is the source of a great loss, strictly local ground conditions are less influential.
- in Japan intensities and losses decrease significantly with the distance, however the local geological and topografical conditions are responsible for some loss increase.

The property losses situates the 1977 Romania earthquake between the Niigata (1964) and Ohitaken-Chubu (1975) earthquakes, Japan, in terms of loss indexes of total loss, as well as for different facilities loss (Kuribayashi 1978). In terms of the ratio of property loss to GNP or National Wealth, the Romania losses are between the Japanese earthquakes of Fukui (1948) and Niigata (1964).

The indirect losses of the 1977 earthquake were much higher than reveal the direct losses, at approximately 2.5 billion US dollars, without considering the debt service.

The other conclusions useful for disaster prevention are:

- for the developing countries, a growth strategy should be associated also with the disaster prevention measures, since any damaging event could bring the economy in a critical situation.
- for the developed countries, the strength of the economy generally allows a recovery of losses using different tactics as incentives for the emergency period (tax exemp-

tion, insurance policies etc.) and the free market self-regulatory mechanism as strategy;
- for the superdeveloped countries, the long term strategy becomes strongly necessary at a higher level, taking into account the costly assets and the international economic interdependence.

From the first category, the example of Romania in 1977 provides the lesson of how difficult is to keep the pace of economic growth and of the recovery after disasters (floods 1970, 1975, earthquake and drought 1977). Entering into the race of international interdependencies and in the world recession conjecture of the 1976-1982, the Romanian economy was hardly stressed, until 1989.

From the second category, Japan in the same decade with Romania shows how the modern disaster prevention could be associated with the growth and the higher social and economic efficiency. And in the third case, there is the Japanese world-wide approach of the anticipated Tokai-Kanto earthquake which is said to bring much more economic loss to other countries than to Japan and globally a 2.6% reduction of the World GNP (The Tokai Bank 1989).

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