Study on seismic losses distribution in Romania and Japan

E.S. Georgescu
Building Research Institute, Bucharest, Romania

E. Kuribayashi
Toyoohashi University of Technology, Japan

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 disaster prevention programs (Kuribayashi 1991, Georgescu 1988).

1. INTRODUCTION

For a long period, the study of seismic losses has been concentrated mostly on engineering aspects. Nevertheless, during the past two decades, there has been a remarkable trend towards an interdisciplinary socio-economic-geological 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 100 km 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 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 (Sand 1984);
- statistical analysis of earthquakes effects on buildings and inhabitants (Georgescu 1984);

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 48°N and the meridians of 25° 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 1,670 deaths, 11,300 injured.
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), Miyazaki-oki (1973), 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


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

<table>
<thead>
<tr>
<th>Damaged assets, lost inventory</th>
<th>Total value (million US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction (buildings, water supply etc.)</td>
<td>1,420.1</td>
</tr>
<tr>
<td>Equipment, installations and transport</td>
<td>104.3</td>
</tr>
<tr>
<td>Raw materials, intermediate products and consumer goods</td>
<td>158.9</td>
</tr>
<tr>
<td>Total</td>
<td>1,683.3</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Economic and social sector</th>
<th>Total damage of loss (million US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>151.1</td>
</tr>
<tr>
<td>Agriculture</td>
<td>74.1</td>
</tr>
<tr>
<td>Transport, communications and retail trade</td>
<td>81.2</td>
</tr>
<tr>
<td>Health, education and social-cultural</td>
<td>165.6</td>
</tr>
<tr>
<td>Housing</td>
<td>1,032.8</td>
</tr>
<tr>
<td>Local industry, utilities and construction</td>
<td>83.1</td>
</tr>
<tr>
<td>Miscellaneous private goods</td>
<td>95.4</td>
</tr>
<tr>
<td>Total</td>
<td>1,683.3</td>
</tr>
</tbody>
</table>

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 4.88% 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

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

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

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry (447.2=100%)</td>
<td>22.96 4.47 6.35 66.22</td>
</tr>
<tr>
<td>Agriculture (124.4=100%)</td>
<td>37.30 8.60 13.67 40.43</td>
</tr>
<tr>
<td>Transport, communication, retail trade (93.2=100%)</td>
<td>55.90 15.45 15.77 12.88</td>
</tr>
<tr>
<td>Health, education and social-cultural (167.3=100%)</td>
<td>88.16 10.82 - 1.02</td>
</tr>
<tr>
<td>Housing (1,003.8=100%)</td>
<td>98.28 1.72 - -</td>
</tr>
<tr>
<td>Local industry, utilities and construction (87.6=100%)</td>
<td>64.38 26.60 3.88 5.14</td>
</tr>
<tr>
<td>Miscellaneous private goods (95.4=100%)</td>
<td>- 100.00 - -</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,048.0=100%</strong></td>
</tr>
</tbody>
</table>

The comparative assessment of selected Japanese earthquakes gives the following ratios of indirect to direct losses:
- 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

<table>
<thead>
<tr>
<th>Earthquake, country, date</th>
<th>Magnit. N (Richter)</th>
<th>Property loss GNP</th>
<th>Property loss National Wealth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kanto, JAPAN, 1923, Sept. 1</td>
<td>7.9</td>
<td>41.50%</td>
<td>7.15%</td>
</tr>
<tr>
<td>Fukushima, JAPAN, 1946, June 28</td>
<td>7.3</td>
<td>15.56%</td>
<td>2.74%</td>
</tr>
<tr>
<td>Niigata, JAPAN, 1964, June 16</td>
<td>7.5</td>
<td>0.70%</td>
<td>0.193%</td>
</tr>
<tr>
<td>Tokachi-oki, JAPAN, 1968, May 16</td>
<td>7.9</td>
<td>0.11%</td>
<td>0.033%</td>
</tr>
<tr>
<td>Miyagi-ken-oki, JAPAN, 1978, June 12</td>
<td>7.4</td>
<td>0.13%</td>
<td>0.041%</td>
</tr>
<tr>
<td>Nihonkai-chubu, JAPAN, 1983, May 26</td>
<td>7.7</td>
<td>0.62%</td>
<td>0.017%</td>
</tr>
<tr>
<td>Vrancea, ROMANIA, 1977, March 4</td>
<td>7.2</td>
<td>5.00%</td>
<td>1.63%</td>
</tr>
</tbody>
</table>

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, 1981.

The index is given by the equation 1:

\[ \text{Individual loss ratio} = \frac{L_k P}{W_k P_0} \]

\( L_k \): 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
\( P_0 \): 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.

\[ \frac{L_k P}{W_k P_0} \]

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

The range of total loss property ratio for different factors is shown in the figure 3. The range of individual loss ratio is also shown in the same figure. The loss ratio of agricultural and industrial facilities is generally lower than the loss ratio of total loss. The loss ratio of electrical power, telecommunication and water supply facilities are less than the total loss ratio. The individual loss ratio of facilities in Japan is much larger than the total loss range fact explained by the variety of facilities, seismic and site conditions and asymmetric 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 become closer to that of the total loss when the size of loss increases (Kuribayashi et al. 1981.)

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 4;
- 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 $S$ was the last and strongest shock.


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:

\[ L_i = f(SA, T, K_1) \]  

where

- \( L_i \): 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)
- \( K_1 \): stock of i-th asset or other substituting index, in monetary value

The second formula is given by the equation 3:

\[ L_i = f(DD, K_1) \]  

where

- \( L_i \): loss of the i-th assets in monetary value
- \( DD \): damage degree expressed as a histogram of losses conditioned by an assumed seismic intensity
- \( K_1 \): stock of i-th asset or 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:

\[ \log R_1 = 0.545M - 1.5 \]  

\[ \log R_2 = 0.520M - 1.5 \]  

- \( R_1 \) and \( R_2 \), the radiiuzes 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 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 controllable 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 econometric 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 topographical conditions are responsible for some loss increase.

The property losses situates the 1977 Romania earthquake between the Niigata (1964) and Ohtaken-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 (1949) 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 1973, 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 1980.

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 such 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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