Multi-Hazard Risk Assessment at Different Levels with Extremum System Application

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Great natural catastrophes in 1950–2005 MUNICH RE

Increase in the losses due to natural disasters is not random phenomenon and mainly dealt with growth of population, industry, infrastructure, commercial and economic activity in large cities, which are prone to different natural and technological disasters.

For taking the proper decision about preventive measures for risk reduction and response measures just after an event the estimations of expected losses due to natural and technological disasters are very critical.
Mathematical expectation of number of fatalities and injuries

\[ M (N_j) = \int_{S_2} \int_{I_{\text{min}}}^{I_{\text{max}}} \int_{0}^{24} P_{Cj} (I) f(x,y,I) \psi(x,y) f(t) dI dt dx dy, \]

- \( M (N_j) \) – mathematical expectation of social losses within the settlement
- \( P_{Cj} (I) \) - law of earthquake impact on population providing the buildings survived damage due to event with intensity \( I \)
- \( f(x,y,I) \) - density function of earthquakes’ intensity \( I \) probabilities within the unit area with co-ordinates \( x, y \)
- \( \psi(x,y) \) - population density within the unit area with co-ordinates \( x, y \)
- \( f(t) \) - function obtained on the basis of statistical analysis of data on population migration during the day time
- \( I_{\text{min}}, I_{\text{max}} \) — maximum and minimum possible earthquake intensity within the given site

**Individual Seismic Risk**

probability of death (or injuries) due to possible earthquake within one year in a given territory

\[ R_e^N = H \cdot V_s (I) = (H/N) \cdot M (N_j) \]

- \( H \) – probability of seismic event per one year
- \( V_s (I) \) - vulnerability of population for the considered settlement
- \( N \) - the number of inhabitants in the considered settlement

**Integrated Individual Risk**

\[ R_e = 1 - \prod_{i=1}^{n} (1 - R_{ei}) \]

- \( n \) — number of considered emergencies of natural and technological character
- \( R_{ei} \) — individual risk due to \( i \)-th emergency
The Extremum System’s mathematical models are based on procedure described in “The Methods of Earthquake Consequences Assessment” and «Methods of Integrated Risk Assessment due to Emergencies of Natural and Technological Character»

System “Extremum” and its versions was developed at Extreme Situations Research Center Ltd. together with Seismological Center of IGE, Russia Academy of Sciences and Institute of Civil Defense, Emercom of Russia
Details of mathematical models and the forms of results visualization at different levels

<table>
<thead>
<tr>
<th>Details of models</th>
<th>Forms of loss and risk presentation on maps</th>
</tr>
</thead>
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<tr>
<td><strong>Global level of loss and risk estimation</strong></td>
<td></td>
</tr>
<tr>
<td>Usage of macro indexes based on countries economic development; Usage of averaged models of hazards and vulnerability functions</td>
<td>Hypsometric layers; Isolines corresponding to different levels of loss and risk; Marks of different colour and size</td>
</tr>
<tr>
<td><strong>Regional level of loss and risk estimation</strong></td>
<td></td>
</tr>
<tr>
<td>Usage of regional models of hazards and vulnerability functions</td>
<td>Hypsometric layers; Isolines corresponding to different levels of loss and risk; Marks of different colour and size</td>
</tr>
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<td><strong>Local level of loss and risk estimation</strong></td>
<td></td>
</tr>
<tr>
<td>Usage of engineering methods of computations; Application of numerical methods for solving the problems</td>
<td>Zones (districts of settlements) of different colour</td>
</tr>
<tr>
<td><strong>Facility level of loss and risk estimation</strong></td>
<td></td>
</tr>
<tr>
<td>Application of numerical methods for estimation of dynamical parameters of ground motion and structures strength capability; analysis of &quot;fault and event trees&quot;</td>
<td>Measurable index of damage, loss and risk</td>
</tr>
</tbody>
</table>
Details of databases on existing building stock

<table>
<thead>
<tr>
<th>Building type according to MMSK-86</th>
<th>City model</th>
<th>Town model</th>
<th>Village model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>Height, m</td>
<td>%</td>
</tr>
<tr>
<td>A</td>
<td>0.33</td>
<td>6</td>
<td>0.43</td>
</tr>
<tr>
<td>Б</td>
<td>0.45</td>
<td>15</td>
<td>0.48</td>
</tr>
<tr>
<td>В</td>
<td>0.14</td>
<td>21</td>
<td>0.08</td>
</tr>
<tr>
<td>C7</td>
<td>0.08</td>
<td>16</td>
<td>0.01</td>
</tr>
</tbody>
</table>

The System EXTREMUM software allows to update the models of settlements

<table>
<thead>
<tr>
<th>Building type according to MMSK-86</th>
<th>Krasnodar City model</th>
<th>Sochi City model</th>
<th>Tuapse City model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>Height, m</td>
<td>%</td>
</tr>
<tr>
<td>А</td>
<td>0.85</td>
<td>3</td>
<td>0.01</td>
</tr>
<tr>
<td>Б</td>
<td>0.45</td>
<td>6</td>
<td>0.11</td>
</tr>
<tr>
<td>В</td>
<td>0.10</td>
<td>15</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0.76</td>
</tr>
</tbody>
</table>

Petropavlovsk-Kamchatsky City – 282 models for districts with uniform building stock

According to MMSK-86 scale:
buildings' classes А1, А2 (from local materials);
buildings' classes Б, Б1, Б2 (brick, hewn stone or concrete blocks);
buildings' classes В, В1, В2 (reinforced concrete, frame, large panel and wooden);
buildings' class С7, С8, С9 (designed and constructed to withstand the earthquakes with intensity 7, 8, 9)
Updating the information about population distribution

DISTRIBUTION OF POPULATION IN ALGERIA

- 2754 cities, towns and settlements
- 6064 cities, towns and settlements
- 55909 cities, towns and settlements
- 180631 cities, towns and settlements

DISTRIBUTION OF POPULATION IN CHINA

- 55909 cities, towns and settlements
INDIVIDUAL SEISMIC RISK ZONATION FOR THE RUSSIAN FEDERATION TERRITORY
INDIVIDUAL INTEGRATED RISK ZONATION FOR THE RUSSIAN FEDERATION TERRITORY

Contribution of technological and natural hazards to integrated risk value
MAP OF INDIVIDUAL SEISMIC RISK FOR THE KRASNODAR REGION TERRITORY

For 764 cities and towns with population more than 1,000 inhabitants values of risk are shown as circles of different size and color.

For small settlements with number of inhabitants less than 1,000 people values of risk are presented as hypsometric layers.

For more than 30% of the Krasnodar region territory the individual seismic risk exceeds the value equal to 1.0 \times 10^{-5}, 1/year
PROCEDURE OF EXPECTED DAMAGE AND LOSSES ASSESSMENT IN “EMERGENCY MODE”

1. The information about the earthquake parameters (origin time, epicenter coordinates, depth, magnitude) is taken automatically from Web sites of Seismological Surveys or received by e-mail.

2. Computations of expected damage extend, social and economic losses due to earthquakes and identification of the effective response measures with the Tool and its versions application.

3. Expert estimation of the obtained results.

4. Taking a decision about expected consequences estimation.

5. Dissemination of messages about expected damage and losses.
Late last month, Iranian authorities revised the number of dead from the December 26 quake, which Bam officials had earlier said killed 43,000.
ESTIMATION OF HUMAN IMPACT DUE TO THE 22 FEBRUARY, 2006 EARTHQUAKE IN MOZAMBIQUE

JRC Alert Tool

EXTREMUM System

PAGER System

Population exposed to shaking

<table>
<thead>
<tr>
<th>MMI Intensity</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>1,000</td>
</tr>
<tr>
<td>IX</td>
<td>8,000</td>
</tr>
<tr>
<td>VIII</td>
<td>32,000</td>
</tr>
</tbody>
</table>

Shaking Intensity

Population per km²

(Data from LandSat 2003)

Characteristics

<table>
<thead>
<tr>
<th>Medical Situation</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population in struck area, persons</td>
<td>2 000 000</td>
</tr>
<tr>
<td>Total killed, persons</td>
<td>37 - 200</td>
</tr>
</tbody>
</table>

Medical Situation:
- including extremely heavily injured: 1 - 40
- severely injured: 4 - 60
- slightly injured: 21 - 900
As a conclusion it should be noticed that the researches carried out within the Russian Federal Programs during more than 10 years, allowed to develop Procedures and a Tool for multi-hazard risk assessment and expected damage and casualty estimation in “emergency” mode. These procedures and tool have been tested under the Council of Europe's Eur-OPA Major Hazards Agreement, as long as earthquake risk is concerned.

For further development of the tool, joint efforts are highly desirable, first of all for the creation of a knowledge base about past event impact, which is necessary for calibration of the tool. In addition, for eliminating, as far as possible, the uncertainties in databases on population, building stock and parameters of simulation models, significant joint efforts are required.
Existing models for hazard, damage and loss assessment should be improved by joint efforts of the scientific community.

Application of concurrent methods developed within PAGER, EXTREMUM and other systems, may increase significantly the reliability of expected loss estimations.

It would be useful to integrate the upgraded tools into a Global Disaster Alert and Coordination System which should develop basing on initiatives by OCHA, JRC and other partners.
Thank you for the attention

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