WEB BASED DECISION SUPPORT TOOL IN ORDER TO RESPONSE TO STRONG EARTHQUAKES

Chen Yong, Chen Q.F., Frolova N., Larionov V.,
Nikolaev A., Pejcoch J., Suchshev S., A.N. Ugarov
World Agency on Planetary Monitoring and Earthquake Risk Reduction,
Geneva, Switzerland,
e-mail: *n_frolova@wapmerr.org*

Keywords: Web based decision support tool, possible damage extent, expected social and economic losses due to strong earthquakes, effective response measures, geographical information system

Abstract

The paper is providing a description Web Based Decision Support Tool "WaveLet" for expected damage and losses assessment due to strong earthquakes, as well as for identification effective response measures. This System takes advantages of GIS "Extremum", "GloSeisRisk" and "EIG/GEM Infobook". The "WaveLet" System development is supported by the World Agency on Planetary Monitoring and Earthquake Risk Reduction.

1. Introduction

Strong earthquakes and secondary processes result in catastrophic human suffering, loss of property and negative consequences. Over 1.6 million people have died in earthquakes during the 20th century. Analysis of natural emergencies including earthquakes occurring all over the world during the last 5 years show that these types of emergencies are growing at average rate of about 5% per year.

The recent disasters in El Salvador and India have reaffirmed the urgency and importance of operative information about possible damage extent, as well as social losses, and shown once again that the decision support tool is necessary which allows possible consequences to forecast within the first hours after events. The goal may be achieved by two ways. The first one is to provide all decision makers by their own tool for the consequences simulation. The second variant is to develop the web based tool, which may be accessible to all interested decision makers on regional or global level.

The “Extremum” System is an example of the second type tool. It operates during 10 years: 1990 – 1997 as a local system, 1998 –2000 as a Web based one. It was developed by joint efforts of “Extreme Situations Research Center” Ltd. and organizations belonging to Russian Ministry of Emergency Situations, Russian Academy of Sciences, which are combined on informational level into the Russian Agency of Monitoring and Forecast of Emergencies. In 1999 – 2000 the System was advanced within the framework of EUR-OPA EDRIM (“Electronic Discussions in Risk Managements”) Program. The System is based on application of new information technologies.

The System is now used in order to provide quick information on damage and casualties assessment of strong earthquakes all over the world
•to the Euro-Mediterranean Centres of EUR-OPA Major Hazards Agreement ,
•to specific national institutions appointed by national authorities,
•to the Executive Secretariat of the Agreement.

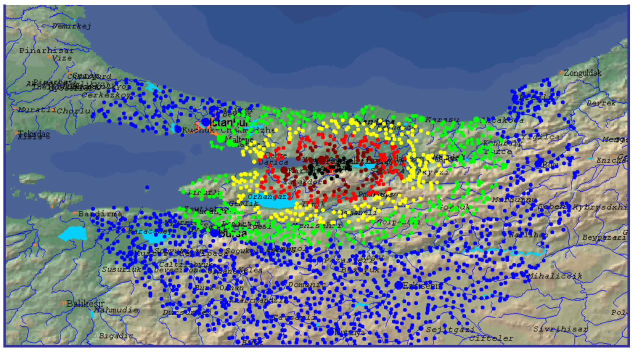
In order to increase the accuracy and reliability of operative damage and losses' assessment with GIS “Extremum” application it is proposed to develop an additional expert block. Within the block the estimations of possible consequences obtained by two independent approaches application are analyzed and expert decision is taken. The development of advanced System has been started under the umbrella of the World Agency of Planetary Monitoring and Earthquake Risk Reduction.

2. Web Based Decision Support Tool “Extremum”

At present the Tool “Extremum” in automative mode allows:

- To read with any pre-setting periodicity the operative information about parameters of strong earthquakes (coordinates, origin time, magnitude, depth) from WEB sites of Seismic Surveys of the world such as National Seismic Information Center of USA (NEIC), European Mediterranean Seismological Center (EMSC, France), Geophysical Survey of Russian Academy of Sciences (Obninsk, Russia);
- To compute the damage extent, possible social and economic losses due to earthquakes and identify the effective response measures;
- To output the results on Web site of the Agency on Monitoring and Forecast of Emergency Situations.

The computation time performance is 10 min. after receiving alert data about strong event. The response scenario may be prepared within 1.5-2 hours after strong earthquake in any country; average error of social losses assessment is 60 %. The example of the System application for losses assessment due to the August 17, 1999 in Turkey showed high efficiency (fig. 1).



Real social losses*:
Fatalities
17 127
Injuries
43 953
Results of computations:
Fatalities
5 410 - 22 340
Injuries
26 520 – 31 220
* Source: ReliefWeb,
Turkey: Earthquake
Situation Report No.24

Fig. 1. Results of possible losses assessment due to 17 August, 1999 earthquake in Turkey with tool “Extremum” application

Table 1 shows that more reliable estimation of possible consequences was made with NEIC alert data usage. The maximum errors in fatalities computations may exceed 100%. The total losses and number of injured, as well as the number of buildings which suffered different damage states are most reliably forecasted.

Table 1. Possible losses assessment due to the August 17, 1999 earthquake in Turkey

No	*Name*	*Computed values* NEIC, Obninsk, EMSC	*Real data*	*Error, in percent*
1	Total losses	36 630 –48 860 persons	61 080 persons*	40 –30
		6 690 – 17 340 persons		90 - 72
		57 880 – 71 190 persons		5.3 - 16
2	Fatalities	5 410 – 22 340 persons	17 127 persons*	68 - 30
		510 –3 930 persons		97 - 77
		9 760 – 34 910 persons		43 - 103
3	Injured	26 520 – 31 220 person	43 953 persons*	39 –29
		6 180 – 13 410 persons		86 - 70
		36 280 – 48 120 persons		17 - 9
4	Homeless	138 190 –155 110 persons	150 000 persons	4 - 8
5	Total number of damaged buildings	55 %	244 500 buildings*	-
6	Number of buildings with $d = 5$	15 %	77 300 buildings*	-
7	The ratio of buildings with $d = 5$ to the	27 %	32 %	5

	total number of damaged buildings (in %)			

*) Source: ***Relief Web OCHA*** – TURKEY: Earthquake Situation Report No.24.

At least one Survey gave the input data, which allows to estimate possible losses with error in interval 20-100 %. The task of the expert is to choose the most reliable Survey for the area under consideration.

The System conceptual framework, its databases on cartographic information, population distribution, data on existing buildings’ stock inventory, on natural and technological hazards, as well as mathematical models are described in (Larionov et al., 1992; Larionov et al., 1993; Shojgu et al., 1992; Larionov, 1999; Larionov et al., 2000; Shakhramanian et al., 2000a; Shakhramanian et al., 2000b; Shakhramanian et al., 2000c; Shakhramanian et al., 2000d).

Its database includes the information massifs (IM), which are combined into four groups. The first IM group allows to describe in details the space under study. This group contains the digital topographic data. As the accuracy, completeness and reliability of this data is concerned, they correspond to the standards for maps of scale M. 1 : 5 000 000; 1 : 1 000 000; 1 : 100 000; 1 : 10 000, 1: 2 000. Small-scaled maps give the general information about the region topography. Large-scaled maps allow the structure of cities and towns to be described.

The second IM group is assigned to describe seismic hazard. It contains catalogs and the information from seismic zonation maps of different scale (review, detailed and microzonation). The data forms the set of thematic maps, tables, networks and lists.

The third IM group provides the description of the different elements at risk: population, buildings and structures, lifeline systems, hazardous facilities et al. The information about buildings may be detailed (type of structure, materials, date of construction, height and so on) and generalized, for instance, the distribution of buildings characterized by different vulnerability classes within the city districts. The information about the population distribution in the buildings and city districts within 24 hours is also included.

The fourth IM group combines the parameters of mathematical models for population distribution, buildings' damage distribution, casualties and fatalities, for rescue teams operations and so on.

All four IM groups of information massifs are interrelated by single coordinate space (coordinate system B, L, H) and by unified code system. The INTERNET as a technical tool for data collecting and presentation of the obtained results is also used.

The mathematical models allows:

- to obtain the distribution of earthquake intensities and peak ground motion accelerations;
- to obtain the fragility laws for the buildings and structures of different type, which are characteristic for the considered area, as well as for the other elements of infrastructure;
- to estimate damage due to scenario and real earthquakes and co-lateral events;
- to compute individual seismic risk and risks due to other hazards;
- to compute individual complex risks.

On the basis of results of computations for scenario and real events the decision is taken about immediate response and/or preventive measures. Figure 2 shows expected buildings damage states distribution due to scenario earthquake for Petropavlovsk-Kamchatsky City. The results was used by local authorities for verification of preventive measures plan for the case of strong event.

Fig. 2. Damage extent due to scenario event for Petropavlovsk-Kamchatsky City (black color -total collapse, brown - partial collapse, red - heavy damage, yellow -moderate damage, green - slight damage, blue - no damage)

The output results of computations are presented as thematic maps, tables, graphs, as well as pages by means of the Internet.

The present Tool is running in WINDOWS environment. It is made up of the unified complex with commercial databases (dBase, ACCESS, ORACLE, INFORMIX) and management systems. The exchange of data with desk top GIS, ARCINFO, MAPINFO is provided. The equipment, which is used for GIS realization, corresponds to the modern standard IBM PC for graphic stations.

3. Web Based Decision Support Tool "WaveLet"

At present the System is under reconstruction in order to become the Distributed Decision Support System (DDSS). The advanced system is called "WaveLet". In order to increase the reliability of possible consequences estimation due to strong earthquakes at least two approaches are planned to be used to simulate possible damage and losses. It is proposed to use the detailed simulation approach foreseen in the System "Extremum" (author of the idea – Dr. V.

Larionov) and approach based on macroeconomic indicators (the author of the idea – Prof. Chen Yong). The application of the approaches will allow experts to avoid the rude mistakes in losses estimations. Figure 3 shows the general framework of “WaveLet” System.

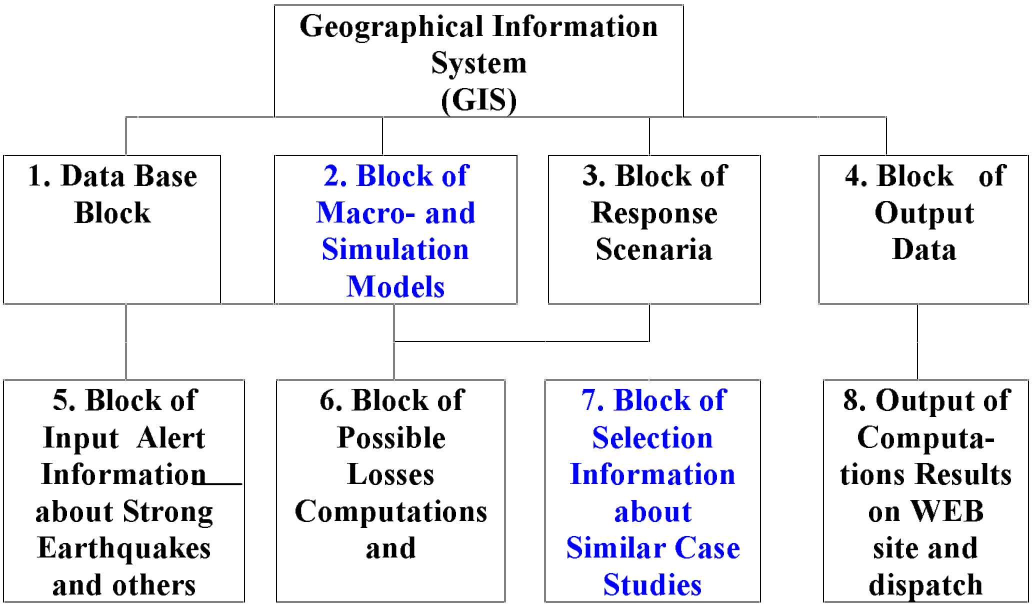


Fig. 3. General GIS framework

The new blocks are shown by blue color. The block no.2 was added by the approach based on macroeconomic indicators, which does not require a detailed inventory database of the structures and facilities in the region. It uses an alternative means of estimating earthquake losses based on several macroeconomic indices such as the Gross Domestic Product (GDP) and population (Chen et al, 1998). Based on the published earthquake loss data during 1980-1998, the relations between GDP and earthquake loss have been formulated empirically for several intensity ranges. The world’s land surface was divided into unit cells with 0.5° × 0.5° in size, the GDP of each cell was apportioned based on its population and the GDP and population of the region to which it belongs. The predicted seismic loss of the cell was then estimated from the seismic hazard probability function, its GDP, and the empirical relation between GDP and seismic loss. Accordingly a global seismic loss map is compiled for intensity VI and above. Employing readily available social economic data as the basis for the vulnerability analysis, the method enables to obtain seismic loss estimates for regions without a detailed inventory of exposed structures or the required collateral geological information. Seismic loss estimates can also be upgraded easily with social economic data collection for the fast developing areas of the world.

The approach uses the “GloSeisRisk” software package for Global Seismic Hazard and Risk Analysis. The “GloSeisRisk” is designed to analysis and demonstration of seismic hazard and risk. The “GloSeisRisk” is a program running in Windows environment, therefore it is easy to combine with the System “Extremum”.

“GloSeisRisk” includes the following world-wide databases:

- Historic earthquake catalog (USGS, since 1800 B.C);
- Instrument earthquake catalog (M_{min}=4.5, 1964-1998);
- Population data (resolution 0.5° × 0.5°, 1998);
- Average attenuation of intensity or Peak Ground Acceleration (PGA);
- National Gross Domestic Product (GDP, 1998);
- World wide earthquake loss data (since 1990).

The advantage of “GloSeisRisk” is that it can provide a reasonable assessment of global as well as regional seismic hazard and risk by using limited data and simplified method. A key contribution of “GloSeisRisk” is the series of global or regional seismic hazard and risk (loss estimate) maps that are produced and updated periodically with new and refined information. “GloSeisRisk” now provides users the quantitative products and information of seismic hazard and risk, including:

- The probability that a certain value of a macroseismic intensity or of a ground motion parameter (i.e. particle acceleration, velocity or displacement) will not be exceeded at any site (oceanic or continental) in the world in various periods of time.
- The expected loss caused by future earthquakes at any site in the world in various periods of time.
- Assess the seismic hazard and loss impact from earthquake scenario in the world (or in a specific region).
- Incorporate the results with GIS for specific output maps.

The table 2 demonstrates the reliability of results obtained with the “GloSeisRisk” application.

Tabl.2. Comparison between actual loss and expected loss of recent earthquakes

Earthquake	Date	Epicenter	Magnitude Intensity	Actual Loss(Million US$)	Expected Loss(Million US$)
Loma Prieta,USA	1989.10.18	37.1N, 121.8W	7.1, IX	5,600	8,525
North Ridge,USA	1994.01.17	34.2N, 118.8W	6.8, IX	15,000	13,070
Kobe, Japan	1995.01.17	34.6N, 135.0E	7.2, IX	100,000	116,986
Sakhalin, Russia	1995.05.27	52.6N, 142.8E	7.6, IX	110	64
Izmit, Turkey	1999.08.17	40.7N, 29.99E	7.8, XI	~20,000	13,240
Ji Ji, Taiwan	1999.09.20	23.7N, 121.1E	7.6	~12,000	18,710
Gujarat, India	2001.01.26	23.36N, 0.34E	7.9	~4,500	3,051

The “GloSeisRisk” offers maximum and enough reliable estimation of possible social and economic losses, which may be used as upper limit (threshold) in comparison with similar estimations provided by the “Extremum” System.

In order to evaluate the best choice for emergency response and preventive measures GIS “WaveLet” will take advantages of “EIS/GEM Infobook” (author of the idea – Dr. Jaroslav Pejcoch). “EIS/GEM Infobook“ is used for integrated decision support in the crisis situations caused by earthquakes with taking into account secondary hazards. The procedure is realized in Block no.7 (fig.3). When the system is applied for scenario identification the following issues are covered (Pejcoch, 2000):

- Logging and messages;
- Mapping;
- Checklists;
- Earthquake damage areas;
- Secondary Incident Response Flowchart for Incident Commander;
- Hazmat information - protective clothing, first aid, fire fighting etc.;
- Buildings’ and structures’ damage;
- Locations of schools and hospitals;
- Briefing and deployments of resources & personnel to earthquake.

The information gathered within the process of emergency response is analyzed and stored in the System database. The efficiency of all actions is estimated. As a result, the examples of positive and negative response measures are available. It is planned to take advantage of this information during operative response to future events.

The “EIS/GEM Infobook“ is a set of programs running in Windows environment, therefore it is also easy to combine with the System “Extremum”. Its technical characteristics for minimal hardware configuration are the folowing: Windows/9x,NT; Processor 200 MHz; 32MB Memory; 1 GB Disk; LAN; WAN. The “EIS/GEM Infobook“ contains the following programs: ”Human Resources”; ” Financials”; ”Logistics”; ”Humanitarian Aid”; ”Field Command”;”Command and Control”. All the abovementioned programs are interoperated through “Message Broker” program.

Figure 3 shows the flowchart with steps for incident commander in the case of chemical facility incident due to strong earthquake.

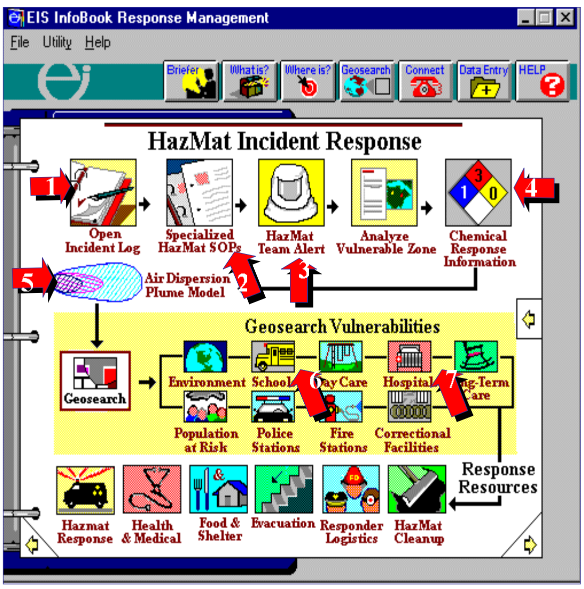


Fig. 3. Example of information flowchart in the case of chemical facility incident due to strong earthquake: 1 - Enter the incident in the Ops Log; 2 - Specialized checklists; 3 - Alert Hazmat Team personnel; 4 - Get chemical response info: for fire hazards, health hazards, Personal Protective equipment, first aid measures, and much more; 5 - Run plume for chemical - NOAA's Aloha is included with EIS/GEM; 6 - Schools to evacuate; 7 – Hospitals.

At present the "EIS/GEM Infobook" is used for ciris management by many state and local governments, federal and military authorities and more than 500 companies.

It is planned that the advanced system "WaveLet", besides the operative consequences' assessment, will provide the results of computations for scenario events according to the request of the registered end-users in the form of tables and maps.

4. Conclusions

As a result of joint efforts within the framework of the World Agency of Planetary Monitoring and Earthquake Risk Reduction the advanced Web Based Decision Support Tool "WaveLet" for operative consequences assessment due to strong earthquakes, as well as for identification effective response measures, has been developed. The three Systems "Extremum", GloSeisRisk" and "EIS/GEM Infobook" were combined at the decision level. At the next stage the combination of the above-mentioned Systems databases and models is planned.

References

Chen Yong, Chan, L. S., Q.Chen, J.Liu, W. Dong and H. Shah, 1998, Assessment of Global Seismic Loss Based on Macroeconomic Indicators, *Natural hazards*, **17**, 269-283.

Larionov, V.I. & Nigmetov, G.M. 1992. *Opredelenie posledstvij razrushenij zdanij i sooruzhenij pri zemletryaseniyakh z uchetom ob'emov, form i strustury zavalov*. Moscow: VIA im. Kujbyssheva.

Larionov, V.I., Shakhramajyan, M.A., Ovsyanik, A.I. Chirikov A.G. & Kozlov, M.A. 1993. *Veroyatnostnaya metodika rascheta sil i sredstv dlya provedeniya inzhenegro-spasatelnykh rabot pri razrushitelnykh zemletryaseniyakh*. Moscow: VIA im. Kujbyssheva.

Larionov V.I., editor. Teoreticheskie osnovy reagirovaniya na chrezvychajnye situastii. Uchebnoe posobie dlya slushtelej I kursantov VIU. Moscow: Izdanie VIU, 1999, 428 P.

Larionov V., Frolova N., Ugarov A. Approaches to vulnerability evaluation and their application for operative forecast of earthquake consequences.// *Proc. of the All-Russian conference "RISK—2000"*, M.: Ankil. 2000, p.480.

Pejcoch J., Presentation on the Moscow Meeting "Contribution to decision-making process in seismic risk management: Models for earthquake damage assessment", June 29- July 1, 2000.

Shojgu, S.K., Shakhramanjyan, M.A., Koff, G.L., Kenzhebaev, E.T., Larionov, V.I. & Nigmetov, G.M. 1992. *Seismic risk analysis, population rescue and life support during catastrophic earthquakes (seismological, methodological and systematic aspects)*. Moscow: State Committee of Russian Federation on Civil Defense and Emergency Situations.

Shakhramanjyan M.A., Nigmetov G.M., Larionov V.I., Frolova N.I., Suchshev S.P., Ugarov A.N. Seismic and Complex Risk Assessment and Management for the Kamchatka Region // *Proc. XII World Conf. Earthq. Engineer.*, Auckland, New Zealand, 2000(a).

Shakhramanjyan M.A., Nigmetov G.M., Larionov V.I., Nikolaev A.V., Frolova N.I., Sushchev S.P., Ugarov A.N. Real Time Damage and Losses Assessment due to Strong Earthquakes // *Proc. XXVII ESC General Assembly*, Lisbon, Portugal, 2000(b).

Shakhramanjyan M.A., Nigmetov G.M., Larionov V.I., Nikolaev A.V., Frolova N.I., Sushchev S.P., Ugarov A.N. Data Exchange Mechanisms for Real Time Damage and Losses Assessment due to Strong Earthquakes // *Proc. XXVII ESC General Assembly*, Lisbon, Portugal, 2000(c).

Shakhramanjyan M.A., Nigmetov G.M., Larionov V.I., Nikolaev A.V., Frolova N.I., Sushchev S.P., Ugarov A.N. Advanced procedures for risk assessment and management in Russia // *Int.J.Risk Assessment and Management*, Vol. Y, No.X, 2000(d).

Short Biographies

Valery I. Larionov, a structural engineer with Agency Monitoring and Forecast of Emergency Situations, EMERCOM of Russia. He has contributed to research of emergency response since 1972. At present he has conducted researches on expected losses assessment due to natural and technological hazards and emergency management with GIS technology application.

Nina I.Frolova, an engineering seismologist with Seismological Center of IGE, Rus. Acad. of Sci., has contributed to studies of earthquake hazards and risk reduction and activities of UNDRO, UNESCO on earthquake preparedness in the former USSR since 1985. She has contributed to the International Decade for Natural Disaster Reduction Projects on risk reduction and management.

Alexey V. Nikolaev, geophysicist, Director of Seismological Center of IGE, Chief of Experimental Geophysics Lab., Joint Institute of Physics of the Earth, Past President of International Association of Seismology and Physics of the Earth's Interior (IASPEI). Has contributed to national and international studies of seismic waves propagation, seismic tomography, nonlinear seismology, induced seismicity

Sergej P. Suchshev, an electronic engineer, Director, Extreme Situation Research Center, has contributed to research and research application in the field of automatic systems for monitoring and forecast of emergency situations of natural and technological types.

Aleksandre N. Ugarov, cartographer, has contributed with Extreme Situation Research Center to research in the field of geographical information systems and application of remote sensing non-traditional materials for the mapping purposes.