0091

A GIS BASED EARTHQUAKE LOSSES ASSESSMENT AND EMERGENCY RESPONSE SYSTEM FOR DAQING OIL FIELD

Li Li XIE[1], Xiaxin TAO[2], Ruizhi WEN[3], Zhengtao CUI[4] And Aiping TANG[5]

SUMMARY

The basic idea, design, structure and function of a GIS (Geographic Information System) based information and decision-making system for earthquake disaster response for Daqing oil field is presented in this paper. The system consists of an information subsystem, analytical modules, a decision-making subsystem and a user interface. The information system consists of 68 coverages. There are also 28 analytical modules. To be aided to managing prearrange, the function of making schemes for six tasks of emergence response is provided in the decision-making subsystem. The functions of the system are realized by means of the advantages of the network analysis of PC ARC/INFO and ArcView.

INTRODUCTION

China is one of the countries suffering from the most severe earthquake disaster over the world. As a rough estimation, China's territory is about 1/14 th of the world continental and its population is about 1/5 of the global one, however, the frequency of occurrence of strong earthquakes is about 1/3 and the earthquake losses (death toll) is about 1/2 of the whole world. Facing a serious situation in reducing earthquake disaster, in China, there are several ten cities and large enterprises taking variety of measures for earthquake disasters protection and reduction and Daqing oil field is one among them.

Daqing oil field is located in northeastern part of the China with population of three hundred thousand and territory of 5,000-kilometer square. It is threatened with the earthquakes. To prevent the potential earthquake hazard and mitigate earthquake losses, the Daqing oil field management bureau launched a comprehensive program, including installation of a digital seismic monitoring system, assessment of potential earthquake damage to buildings and infrastructures, strengthening existing weak structures and a GIS based emergency response system. The objectives of the latter project are to provide an efficient tool in decision-making for emergency responding after an occurrence of the earthquake, particularly the occurrence of devastating earthquake.

STRUCTURE OF THE SYSTEM

The system is a GIS based decision-making system. It can be used for seismic hazard assessment, seismic damage forecast, post-earthquake quick evaluation of seismic losses and decision-making for emergency response as well as post-quake recovering. Figure 1 illustrates the general structure of the system in terms of its application in post-earthquake response.

The system is composed of the following four sub-systems:

(1) Information subsystem
(2) Analytical module subsystem

[1] *Institute of Engineering Mechanics, China Seismological Bureau*
[2] *Institute of Engineering Mechanics, China Seismological Bureau*
[3] *Institute of Engineering Mechanics, China Seismological Bureau*
[4] *Institute of Engineering Mechanics, China Seismological Bureau*
[5] *Institute of Engineering Mechanics, China Seismological Bureau*

(3) Computer aided decision-making for emergence response, and
(4) System integration and user interface

The information subsystem is designed for acquiring, archiving, displaying, updating, processing and analyzing spatially distributed data and attributes in a quick and efficient mode. The analytical module subsystem provides a set of calculating and analyzing procedures outside the GIS environment, for further application in emergency response and/or post-quake recovering, such as isoseismals generation of a scenario earthquake, damage evaluation, economic losses assessment, dead and injuries estimation and so on. The decision-making subsystem provides the user with some computer-aided decisions based on the damage, losses and the preset target. The system integration and user interface is designed to integrate all parts of the system into one environment for easy communication between the subsystems and a friendly interface for various users at various levels.

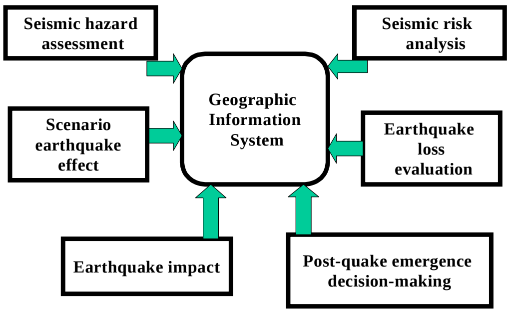


Figure 1: General structure of the system

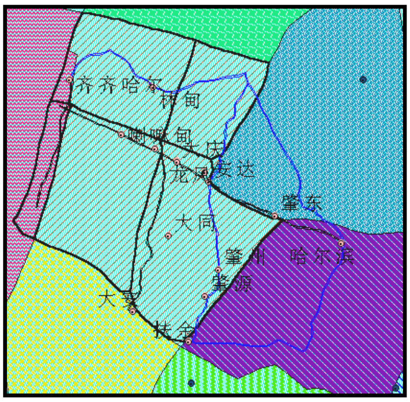


Figure2: The seismic environment at Daqing

INFORMATION SUBSYSTEM

The subsystem is composed of seismic tectonic information sub-subsystem (STIS), engineering environmental information sub-subsystem (EEIS), damage and loss information sub-subsystem (DLIS) and emergence information sub-subsystem (EIS). They are all space database, the third one is designed for updating every time after damage and losses evaluation for a scenario earthquake.

The STIS contains all data related with potential seismic hazard, such as:

- Geographical location coverage for the whole Daqing oil field and its surroundings
- Earthquake monitoring network coverage
- Destructive earthquake coverage
- Instrumentally recorded earthquake coverage
- Seismic fault coverage
- Seismo-tectonic province coverage
- Seismic zoning coverage

In figure 2, the seismic environment at Daqing oil field and its surroundings is shown from an ArcView project composed of some coverages of STIS.

The EEIS is the another significant major database describing the geographical information of the entire engineering environment, such as important buildings, building in groups, infrastructures, lifeline systems, equipment and facilities for petroleum production, etc. The coverages of the EEIS are as following:

- Coverage of important individual buildings
- Coverage of buildings in groups
- Coverage of buildings in blocks
- Coverage of site condition with drilling holes
- Coverage of transportation network (roads, bridges and culverts)
- Coverage of water supplement network
- Coverage of power supplement network
- Coverage of communication system
- Coverage of oil pipeline network
- Coverage of gas pipeline network
- Coverage of special structures

Some coverages listed herewith include two kinds of space feature, points and arcs for various stations and pipelines. In figure 3 and 4, the parts of the building in-groups and individual building coverages are shown from two ArcView projects composed of some coverages of EEIS.

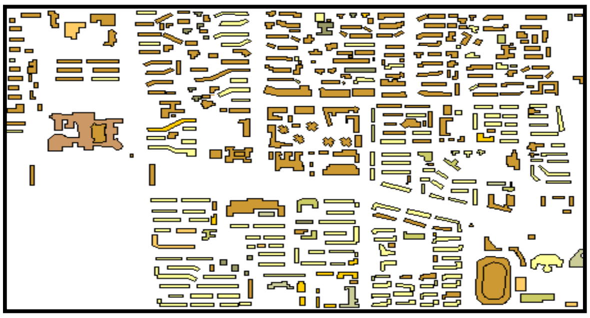


Figure 3: Building in groups

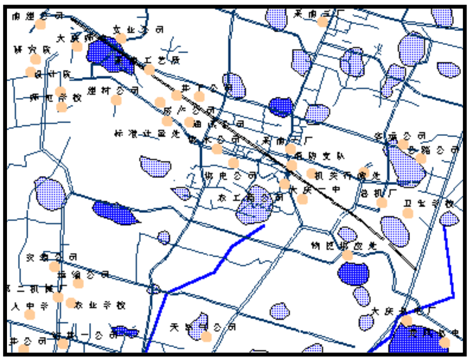


Figure 4: Individual Building

The DLIS contains all information of damage and loss under a scenario earthquake. In figure 5, the user-face of the earthquake parameter input is shown. There are two ways to input the epicenter location. One is tabular input, either geographic coordinates in degree, minute and second or in UTM projected coordinates is acceptable. The other is an interactive input, the epicenter could be pointed on the earthquake environment coverage with the cross. In figure 6, a part of the power supplement system overlaid by the isoseismals of a scenario earthquake with magnitude 6.0 is shown from a ArcView project composed of some coverages of DLIS. The detail damage and loss information could be displayed, queried and tabulated for output easily from DLIS.

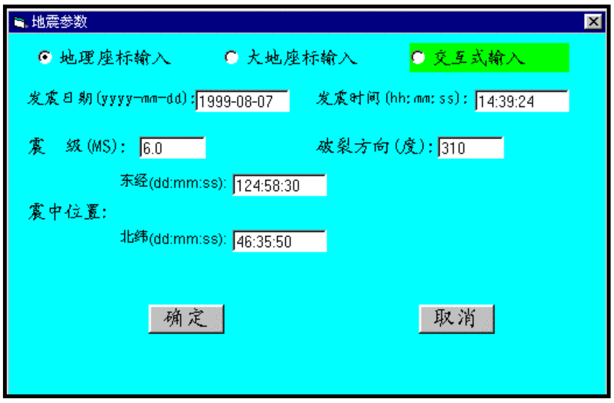


Figure 5: The user-face for earthquake parameter input

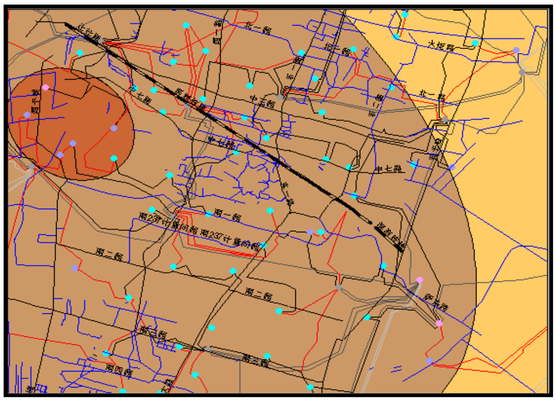
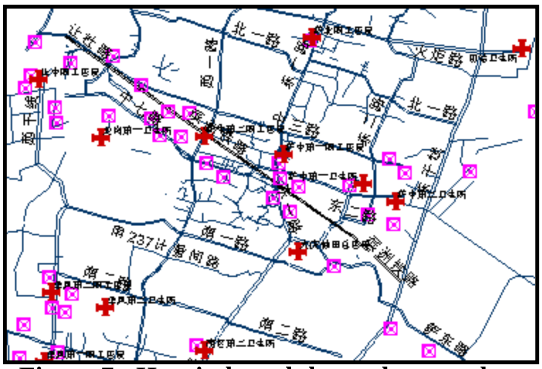


Figure 6: Power supplement system with intensity distribution

The EIS contains information available for post-earthquake emergence response in coverages as follows:

- Coverage of induced disaster sources
- Coverage of fire stations
- Coverage of settlement places
- Coverage of relieve goods
- Coverage of rush repair stations of transportation system
- Coverage of rush repair stations of water supplement system
- Coverage of rush repair stations of power supplement system
- Coverage of rush repair stations of communication system
- Coverage of rush repair stations of oil pipeline system
- Coverage of rush repair stations of gas pipeline system
- Coverage of police stations

In Figure 7 and 8, the distribution of hospitals, settlement places, police stations and the induced disaster sources are shown. The information in EIS includes the capacities, demands, as well as their damages and losses, and the impedance of the post-earthquake transportation system.



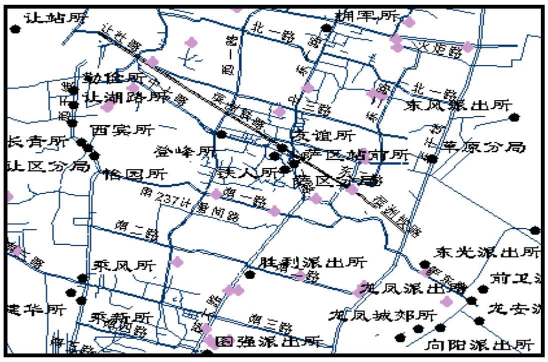


Figure 7: Hospitals and the settlement places **Figure 8 : Induced disaster sources and police stations**

2. ANALYTICAL MODULE FOR SEISMIC DAMAGE ASSESSMENT

This system provides a comprehensive algorithm to evaluate damage of buildings and infrastructures under a scenario earthquake in a near real-time mode. For example, the formula used in the simplest algorithm is as follows:

$$\mathrm{P}[D_j] = \sum_{6}^{10} P[D_j / I] \quad \mathrm{P[I]} \tag{1}$$

where D_j (j=1,2,3,4,5) is a damage index vector of a given type of structures, while D_j =0, 0.2, 0.4, 0.6, 0.8 and 1.0 represents intact, light damage, moderate damage, severe damage and destroyed, respectively; $P[D_j]$ denote the vulnerability matrix of the structures in terms of the probabilities of damage at various level to the concerned structures under the given earthquake intensity I (from 6 to 9), were obtained by statistical and /or analytical process; P[I] is called seismic hazard vector represented by exceeding probabilities of seismic intensities and derived from seismic hazard assessment. Table 1 listed a matrix as an example for ordinary multi-story masonry buildings.

Table1: Vulnerability Matrix

INTENSITY	INTACT	SLIGHTLY DAMAGED	MODERATELY DAMAGED	SERIOUSLY DAMAGED	DESTROYED
VI	0.5965	0.2745	0.0870	0.0339	0.0081
VII	0.5134	0.2349	0.1346	0.0812	0.0359
VIII	0.3616	0.2142	0.1895	0.1468	0.0880
IX	0.2056	0.1772	0.2108	0.2212	0.1852
X	0.0653	0.0959	0.1792	0.2689	0.3907

Of course, the algorithm for network is more complicated.

3. SEISMIC LOSSES ASSESSMENT

Regarding the seismic losses, economic losses and the losses of life, including death and injured, are concerned in this system. Economic losses usually comprise direct economic losses and indirect losses. Due to the extreme complexity of estimating indirect economic losses, only direct losses are taken into consideration in this project.

Seismic economic losses assessment

The direct economic losses include the repairing cost for damaged buildings and facilities and cost of the indoor properties damaged during earthquake. Following formula is applied in this system,

$$L(I) = \sum_j \sum_s b_s(j) B_s + \sum_j \sum_s Q_s(j) W_s + \alpha N F(t) \tag{2}$$

where $L(I)$ denotes the total economic losses for an area affected by an earthquake with intensity I; $b_S(j)$ is the losses ratio of the buildings of category s (as well as equipment and facilities) damaged at j-th level; B_S is defined as the total cost for the buildings of s category; $Q_S(j)$ as ratio of the losses of the equipment, facilities and other indoor properties damaged at *j*-th level in buildings of category *s* to their total cost W_S; *N* is defined as the cost for normal daily production; α ,the production reducing factor and *F(t)*, production recovering function, which could be approximately estimated. For example, in case it takes T days to recover the production to full run, the losses from production can be approximately estimated as $\frac{1}{2}aNT$.

Assessment of life losses

The losses of life during earthquake depend largely on the damage of the buildings, occurrence time of earthquake as well as the quality of rescue work and seismic emergency response measurement. In this paper, a simple way is applied for a rough estimation of the seismic death toll by using the following expression

$$ND = (A_1R_1 + A_2R_2 + A_3R_3)\rho \qquad (3)$$

where *ND* means the total number of the death toll; A_1 , A_2 and A_3 are total construction area(M^2) of the collapsed, seriously damaged and moderately damaged structures respectively; R_1 , R_2 and R_3 are the death rate for the buildings encountered collapse, serious damage and moderate damage respectively and ρ is the density of population in the buildings. The values of R_1 , R_2 and R_3 are shown in Table 2.

Table 2: Rate of Seismic Death Toll

DAMAGE LEVEL	INTACT	SLIGHT	MODERATE	SERIOUS	COLLAPSE
DEATH RATE	0.0	0.0	0.00001	0.001	0.017*
INJURY RATE	0.0	0.0003	0.0034	0.034	0.89

Note: "*" this value is for the daytime and 0.034 for the nighttime

4. DECISION-MAKING FOR SEISMIC EMERGENCY RESPONSE

The decision-making subsystem for seismic emergency response provides the whole system with functions of resources allocation and route search. These functions are extremely significant to run the emergency response program that includes rescuing program, relief program, medical treatment program, water and food supply program, transportation and communication rush repair program, shielding program, public security program, recovering program and so on. For example, the medical treatment program will provide information to government for making decision on how many physical doctors and where should be sent to based on the number of injuries evaluated by the life losses assessment module. And the water-food supply system will advise the decision-makers how much drinking water and food are needed for a specific field based on the result of the extent of the damage to buildings evaluated by the seismic damage assessment module. The transportation program will envisage the distribution of damage to the road and decide the optimum route for a quick and safe access to the target place. Figure 9 and 10 demonstrate

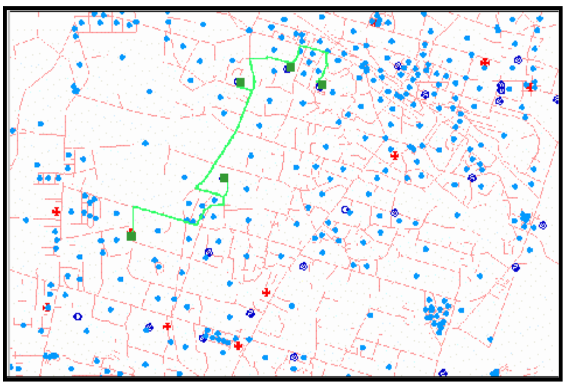


Figure 9: A medical treatment decision scheme

Figure 10: The front page of the system

5. SYSTEM INTEGRATION AND USER-FACE

To start the system, double click the icon in Windows desktop. There are two working situations, daily management and post-earthquake emergence. The main work in daily management is to update, manipulate and operate the information subsystem. There are five buttons in the user-face of daily management, for managing data as follows:

(1) Regional earthquake environment

(2) Engineering site condition

(3) Engineering environment

(4) Lifeline system environment

(5) information available for post-earthquake emergence response

There are five buttons in the user-face of post-earthquake emergence, to execute the following tasks:

(1) Input earthquake parameters

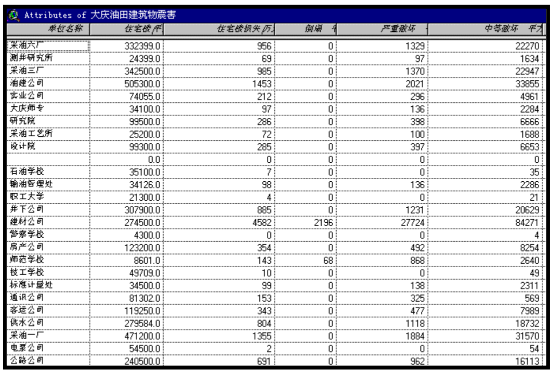
(2) Assess the damages and losses

(3) Query the damage

(4) Make decisions for emergence response

(5) Generate report

In figure 11 and 12, a damage and loss table of buildings and a report are shown.



Attributes of 大庆油田建筑物震害

单位名称	住宅楼/平	住宅楼损失/万	倒塌	严重破坏	中等破坏 平方
采油六厂	332399.0	956	0	1329	22270
测井研究所	24399.0	69	0	97	1634
采油三厂	342500.0	985	0	1370	22947
油建公司	505300.0	1453	0	2021	33855
实业公司	74055.0	212	0	296	4961
大庆师专	34100.0	97	0	136	2284
研究院	99500.0	286	0	398	6666
采油工艺所	25200.0	72	0	100	1688
设计院	99300.0	285	0	397	6653
	0.0	0	0	0	0
石油学校	35100.0	7	0	0	35
输油管理处	34126.0	98	0	136	2286
职工大学	21300.0	4	0	0	21
井下公司	307900.0	885	0	1231	20629
建材公司	274500.0	4582	2196	27724	84271
警察学校	4300.0	0	0	0	4
房产公司	123200.0	354	0	492	8254
师范学校	8601.0	143	68	868	2640
技工学校	49709.0	10	0	0	49
标准计量处	34500.0	99	0	138	2311
通讯公司	81302.0	153	0	325	569
客运公司	119250.0	343	0	477	7989
供水公司	279584.0	804	0	1118	18732
采油一厂	471200.0	1355	0	1884	31570
电泵公司	54500.0	2	0	0	54
公路公司	240500.0	691	0	962	16113

Figure 11: A damage and loss table

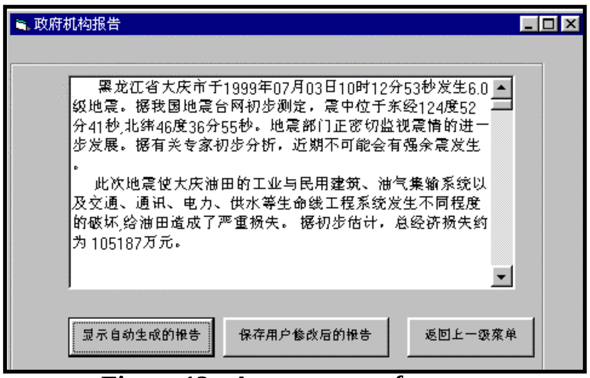


Figure 12: A report user-face

6. CONCLUSION

It is no doubt that the seismic emergency response system will be useful and helpful to the local authority responsible for disaster management. However, the presented system has not been experienced from any real earthquake and even not tested in a real case and therefore the examination of system's effectiveness is need in the recent future.

7. REFERENCES

1. Stephanie et al., “Methodologies for Evaluating the Socio-Economic Consequences of Large Earthquake”, Earthquake Spectra, Vol.2, No.4, 1997.
2. Tang Aiping et al., “Application of GIS to post-earthquake emergence response”, Journal of Natural Disasters, Vol.7, No.3, 1998
3. Tao Xiaxin et al., “Application of an AI and GIS based seismic hazard assessment procedure to seismic zonation in Taiyuan-linfen region ”, Journal of Earthquake Research in China, 1996
4. Tao Xiaxin et al., “GIS application in seismic hazard assessment of China”, Proc. of the GSHAP regional workshop of the eastern and southern Asia, 1994
5. Wen Ruizhi et al., “A GIS Based Seismic Disaster Prevention System for lifeline system”, Journal of Natural Disasters, Vol.7, No.3, 1998

Xie Li-Li et al., “A GIS and AI based seismic hazard assessment and information system”, Journal of Natural Disasters, 1995