RESEARCH ON URBAN EARTHQUAKE EMERGENCY MANAGEMENT SYSTEM

Jie Gao[1], Fengxin Zhao[2] and Qimin Feng[3]

[1] *Assistant research fellow, Dept. of Earthquake Disaster Prevention Technology, China Earthquake Disaster Prevention Centers, Beijing. China*

[2] *Professor, Dept. of Earthquake Disaster Prevention Technology, China Earthquake Disaster Prevention Centers, Beijing. China*

[3] *Professor, College of Engineering, Ocean University of China, Qingdao. China*

Email: juarrygao@hotmail.com fx_zhao@sina.com fqmghy@sina.com

ABSTRACT :

It has been demonstrated repeatedly that a timely macro-understanding of seismic disaster scenarios and effective emergency management always play the key roles in aftershock rescue and disaster mitigation. In our research, Urban Earthquake Emergency Management System (UEEMS), as a comprehensive data integration and analysis system for seismic emergency management, is developed on ArcView9.0 and Oracle 9i. UEEMS is mainly composed of four subsystems: central control system (CCS), earthquake situation analysis system (ESAS), earthquake emergency response system (EERS) and earthquake emergency command system (EECS). The purpose of this paper is to introduce the structure and functions of four subsystems, and the establishment of system database of UEEMS. CCS is in charge of all sorts of information transmission among other subsystems. By means of interface design, the mechanism of processing and analyzing earthquake precursor and observation data is embedded in ESAS to predict the parameters of forthcoming earthquake. According to these parameters, the estimation of seismic emergency levels can be more rapidly made in EERS based on the earthquake influence field and the spatial variations of seismic intensities. Furthermore, using spatial analysis of GIS and embedded disaster assessment models, EERS can illuminate the spatial variations of seismic catastrophe. Finally in EECS all estimated data about earthquake disaster affection will be continuously modified in light of real-time feedback on earthquake stricken areas. Meanwhile the demands of rescue materials and the countermeasures about emergency command and will be offered to decision makers.

KEYWORDS: Earthquake emergency management, Earthquake emergency command, Seismic disaster assessment, GIS

1. INTRODUCTION

With the faster development of urbanization in China, how to improve the capability of disaster resistance and emergency response has taken the first place in urban security management. In very low-frequency, high-consequence events such as earthquakes, getting earthquake information from forecast and taking related actions perhaps is the best way to minimize negative consequences to individuals and social systems. Unfortunately, mechanisms that trigger earthquakes and the probability of disaster are difficult to anticipate yet, so the earthquake forecast cannot reach the satisfactory accurateness. As far as earthquake early warning is concerned, even though giving the alarm before a main shock attacks cities is theoretically practicable (Liao Xu and Huang He, 2002; Li Shanyou et al., 2004) and some earthquake early warning systems have been established and put into practice (Adrian grigorie and Alexandru 2006) in some countries, all these systems do work on the assumption that the epicenter is far away enough to provide adequate alarm time which however, cannot always be obtained in reality (R.M.Allen,2003). Under this circumstance that earthquake forecast and early warning don’t work effectively enough, faster earthquake emergency response and better management certainly become the most economical and practical way to reduce seismic hazards.

There are several famous emergency management institutions which have been established in the world including the Disaster Prevention Center in Japan and the Federal Emergency Management Agency (FEMA) in U.S. These institutions are usually equipped with technical analysis and decision-making support systems to realize disaster information collection and transmission, disaster affection assessment and rescue resources coordination. In China, researches on urban earthquake emergency management system (UEEMS) have been made since the ninth five-year plan. Shuai Xianghua preliminarily proposed the framework of UEEMS (Shuai Xianghua et al., 2001); Sheng Jialun described the key technique and general design of earthquake emergency system (Sheng Jialun et al., 2005). In recent five years, China Seismological Bureau (CSB) also organized experts to research the establishment of UEEMS successively in several metropolises and achieved prominent success. Notwithstanding all domestic and overseas achievements mentioned above, there are still some aspects need to be improved. For example, more attention was paid to seismic disaster prediction and it has not been emphasized enough that the application of emergency management theories in some emergency response systems which have already been established in several chinese cities. Therefore, how to enhance UEEMS's capability of aided decision and real-time disaster data collection and analysis is essential to improve the efficiency and accuracy of earthquake emergency.

This paper firstly clarifies the organization and procedure of earthquake emergency and the objectives of UEEMS on the basis of emergency management theories and related past work in the last decade. Following the presentation, the general structure and fundamental functions of UEEMS are illuminated with full consideration of the real demands in emergency command. Moreover, the database design and program implementation based on ArcView9.0 are also described in detail. Finally the paper concludes with demonstrations of how UEEMS can be used in earthquake emergency command.

2. ORGANIZATION AND PROCEDURE OF EARTHQUAKE EMERGENCY

2.1. Organization System

Earthquake emergency management (EEM) is a complicated task which involves many economic, social and technical factors. So it is important to set up the coordinated organization to arrange resources and deal with urgent events. The organization system consists of governments, social rescue institutions, media and commonalties in which governments and social rescue institutions play the leading roles. Governments act as supervisors to issue policies, plans and temporary emergency countermeasures, to organize and supervise actions of social rescue institutions, media and commonalties. Therefore, collecting and integrating the data related to EEM from many separated departments as soon and accurate as possible is obviously significant for governments and that is one of the reasons why it is necessary to develop UEEMS. Social rescue institutions, such as police, hospitals, even armies, are actually the leading actors in the implement of countermeasures. For this goal, it is vital to keep the connection between governments and institutions reliable and unblocked. Hence, how to ensure the disaster information and emergency decisions are issued to the rescue institutions in time and how to take full advantage of social rescue resources are definitely the problems that need to be concerned in EEM. The structure of organization system of EEM is shown in figure 1.

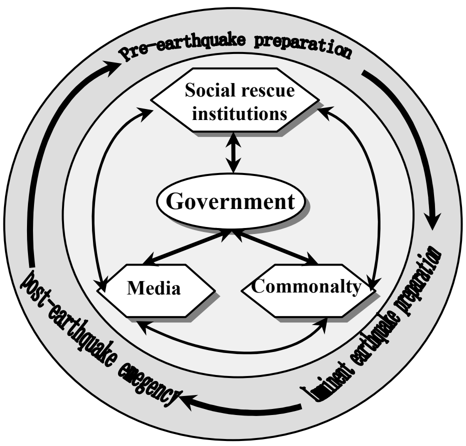

Figure 1 Organization system of EEM

2.2. Procedure of EEM

The entire procedure of EEM can be divided into three phases: pre-earthquake preparation, imminent earthquake preparation and post-earthquake emergency. In the first phase, the emphasis should be placed on the followings: 1) Recording and accumulating the data about earthquake precursor and observation; 2) Drawing and revising emergency plans with the development of urban economy and population; 3) Strengthening the propaganda of knowledge about seismology and strategies about earthquake emergency; 4) Reinforcing or reconstructing the structures and infrastructures with weak anti-seismic abilities.

In the second phase, the main task is to estimate the magnitude and location of forthcoming earthquake, to assess the possible damage of constructions and casualties, and furthermore to reckon the necessities for rescue. Imminent earthquake preparation concerns so many links, such as earthquake monitoring, earthquake situation consultation, earthquake disaster prediction and so on, that any misestimation or inaccuracy in each link will directly lead to a misunderstanding about disaster affection. Thereby it cannot be too much to keep studying on these assessment methods. In this paper some relatively matured assessment methods are programmed into several modules in UEEMS.

The last phase is the kernel of whole procedure. In this phase, decision makers have to modify the details in written plan and rectify the errors in foregoing estimations based on the real-observed parameters of occurred earthquake and the real-time data about disaster situation. Moreover, the new countermeasures and coordination instructions for all the social rescue institutions， media and commonalties should be promulgated as soon as possible. It is obvious that the timely information transmission between command center and disaster areas is the key to guarantee the rescue efficiency and effect.

3. OBJECTIVES OF UEEMS

3.1. Organization System

Based on the procedure of EEM mentioned above, the main objectives of UEEMS can be illuminated as:

1) Data storage and integration: Earthquake emergency management involves many data of different types and formats which are usually dispersed into different social departments and institutions. It is important for UEEMS to collect, process, integrate and store the fundamental data with a uniform format to facilitate data management;

2) Rapid earthquake emergency response and disaster assessment: The basic step of earthquake emergency response (EER) is to obtain the related information (e.g. epicenter location, magnitude) about an earthquake before or after it occurs as soon as possible by means of seismic situation consultation (SSC) which has been regarded as a substituted approach to predict seism instead of earthquake forecast. SSC is a mechanism to approximately speculate the location, maximum possible magnitude and occurring time of the next incoming earthquake in a long or short term by some seismologists and experts based on the monitoring data from geomagnetism and earthquake waves, natural phenomena, results of seismic hazard assessment, statistics and experiences of historical earthquakes. With OA development and interface design, MAPSIS and EIS2000, two isolated analysis software for earthquake information and precursory data, were integrated into SSC submodule which was embedded in UEEMS and provided essential earthquake parameters for emergency level judgments. The next step of EER is to estimate the emergency level based on the spatial variation of seismic intensities. In UEEMS, the devastation degree and influential range of an earthquake can be represented by the emergency level which is defined in light of the spatial variation of seismic intensities. The detailed classifications of emergency levels are specified in Table 1 and the main process of estimating emergency levels is as follows: a) Drawing seismic influence fields based on earthquake parameters getting from SSC module before earthquakes or from the real

monitoring data after earthquakes; b) Identifying the seismic intensity of every district in a city and around regions by spatial superposition analysis between seismic influence fields and district layers; c) Estimating the emergency level according to spatial variation of intensities and the classifications shown in Table 1.

After ascertaining the emergency level, UEEMS can assess the possible seismic disasters and create various thematic maps with the powerful data-visualization functions of ArcView9.0 to demonstrate the seismic catastrophe scenarios and damage statistics. This information is helpful to modify and implement the existing plan effectively to improve coordination, eliminate or at least mitigate time delay, and reduce casualties and economic losses.

Table 1 Classifications of seismic emergency levels

Emergency Level	Descriptions	
Level I	Red Alarm.	There are some districts in which seismic intensities are over VII
Level II	Orange Alarm	Seismic intensities in all districts are below VII and some are over VI
Level III	Yellow Alarm	The maximum of seismic intensity in all districts is below VI
Level IV	Blue Alarm	No obvious damage in all districts and no necessity for emergency

(3) Earthquake emergency command (EEC) and aided decision-making: Because the specific disaster data cannot be totally estimated or simulated, the real-time feedback information about seismic disasters is highly needed for further emergency command and rescue. Thus the mechanism of fast collecting, reporting and analyzing real-time disaster data was established and embedded in UEEMS to modify the estimated results about hazards and provide the supportive information for countermeasures. The seismic disaster information (SDI) usually comes from social rescue institutions and commonalties. Considering the variety of data sources and the diversity of special knowledge background of commonalties, how to ensure that all reported data can be successfully identified and rapidly stored and integrated by computers is a big problem that has to be solved. In the design of UEEMS, two measures are taken to guarantee the validity of SDI. Firstly, several people who live in different communities of the city or work for some rescue institutions are picked up and trained as professional SDI reporters to take charge of the feedback of disaster data in their residential communities as soon as ruinous earthquakes occur. Secondly, based on the historical seismic disaster data and the relevant national regulations, the classifications of SDI are concretely determined and shown in Table 2. Meanwhile the report forms corresponding to each classification of SDI are also be formatted to facilitate the data record and input for both succors who distribute on disaster spots and operators who work in the emergency command center to write down SDI from all sources.

Table 2 Classifications of seismic disaster information

Type	Contents
Casualties	The number and location of injured or dead people
Construction damage	The number, location and damage degree of buildings
Power supply system damage	The number, location, damage degree and influence areas of broken transformer substations and telegraph poles
Water supply system damage	The number, location, damage degree and influence areas of broken waterpipes and water factories
Gas supply system damage	The number, location, damage degree and influence areas of broken gaspipes and gas stations
Transportation system damage	The number, location, damage degree of broken bridges and roads and the regions of traffic jam
Communication system damage	The number, location, damage degree and influence areas of broken base stations
Earthquake-induced hazards	The number, location, damage degree and influence areas of fires, explosion, radiations and flood
Other kinds of disasters	The number, location, damage degree and influence areas of riot, diseases, and so on

With continuously receiving the feedback of SDI from disaster spots, UEEMS will repeatedly keep calling some embedded analysis models to recalculate and revise the predicted disaster scenarios and furthermore to estimate the demands of rescue materials, for example, plasma, bandage, stretchers, tents, clothes, instant food and water. All these aided decision information will be automatically displayed on the thematic maps for emergency command to help commanders or decision makers to arrange and coordinate all kinds of rescue resources.

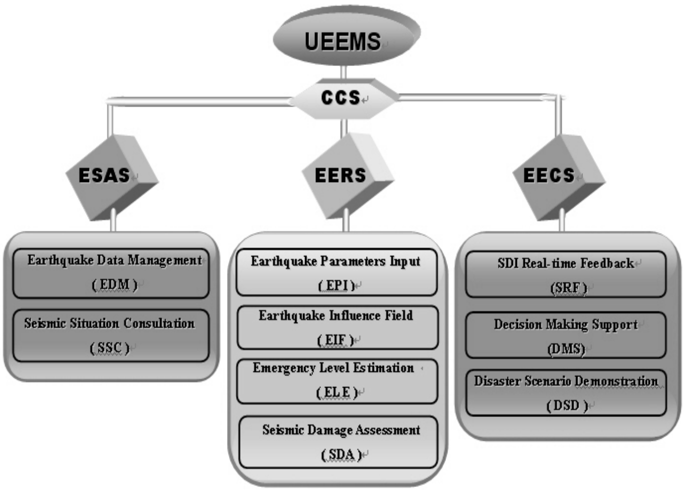

Figure 2 Logical structure of UEEMS

4. UEEMS FRAMEWORK AND FUNCTIONS

4.1. Framework of UEEMS

UEEMS logically consists of three subsystems including central control system (CCS), earthquake situation analysis system (ESAS), earthquake emergency response system (EERS), and earthquake emergency command system (EECS). Each of these subsystems is composed of several submodules. The detailed structure of UEEMS is illuminated in Figure 2. Almost all these modules are developed in VB program language and integrated in ArcView9.0 with COM and AO development technologies.

4.2. Functions of submodules of UEEMS

Central control system (CCS)

● CCS is in charge of all the data transmission among different modules and information issue by the communication with media.

Earthquake situation analysis system (ESAS)

● Earthquake data management (EDM) submodule: EDM answers for all the maintenance, preprocession, translation and storage of seismic precursory and observation data.

● Seismic situation consultation (SSC) submodule: SSC is to call MAPSIS and EIS2000 by the designed interfaces to analyze all the information and present the comprehensive analyses to the experts who will consult about these results and estimate parameters (epicenter, magnitude and time) of the incoming earthquake.

Earthquake emergency response system (EERS)

● Earthquake parameters input (EPI) submodule: EPI connects ESAS and EERS. The earthquake parameters from SSC or from real observations will be stored into database and transferred to EIF in EPI.

● Earthquake influence field (EIF) submodule: Using methods and attributes of AO objects in ArcView9.0, EIF can draw an earthquake influence field in a layer based on the inputting parameters and the attenuation laws of ground acceleration or seismic intensities. All These attenuation laws are prestored in database and there is an interface in EIF allowing users to choose the appropriate laws, add new ones or delete old ones.

● Emergency level estimation (ELE) submodule: In ELE, according to the three steps of estimating emergency levels mentioned above, the seismic intensities of each district in the city and around regions are listed in a table and the emergency level is expressed by a warning message with different colors (red, orange and yellow) and sounds. Meanwhile, the corresponding emergency plan stored in database will be opened.

● Seismic damage assessment (SDA) submodule: SDA is to calculate the vulnerability matrixes of buildings and lifeline engineering with the embedded models and to assess the casualties and economic losses. All these calculation and assessment results will be stored in system database.

Earthquake emergency command system (EECS)

● SDI real-time feedback (SRF) submodule: SRF realizes the inputting and strage of real-time feedback of

SDI into system database. SRF is built in the Browser/Server pattern so that all the professional SDI reporters can log-in on any terminal computers through the special governmental LAN which connects the core server and the other client computers.

● Decision making support (DMS) submodule: In DMS, the seismic disaster scenarios from SDA submodule are repeatedly modified based on the real-time SDI feedback. Meanwhile, the demands of rescue materials are also calculated by using some special analysis models embedded in DMS and furthermore the corresponding countermeasures can be inferred from expert knowledge base.

● Disaster scenario demonstration (DSD) submodule: DSD can create many kinds of thematic maps, such as unique value map, bar chart map, pie chart map, etc, to visualize the modified seismic disaster scenarios and the decision-making supportive information. For example, the severity of damage in every district can be rendered with different colors so it is clear to find the heavy disaster areas. In addition, the prior countermeasures aiming at these heavy disaster areas and the rescue materials requirements are labeled on the maps.

The data flow in real operation of UEEMS is described in Figure 3.

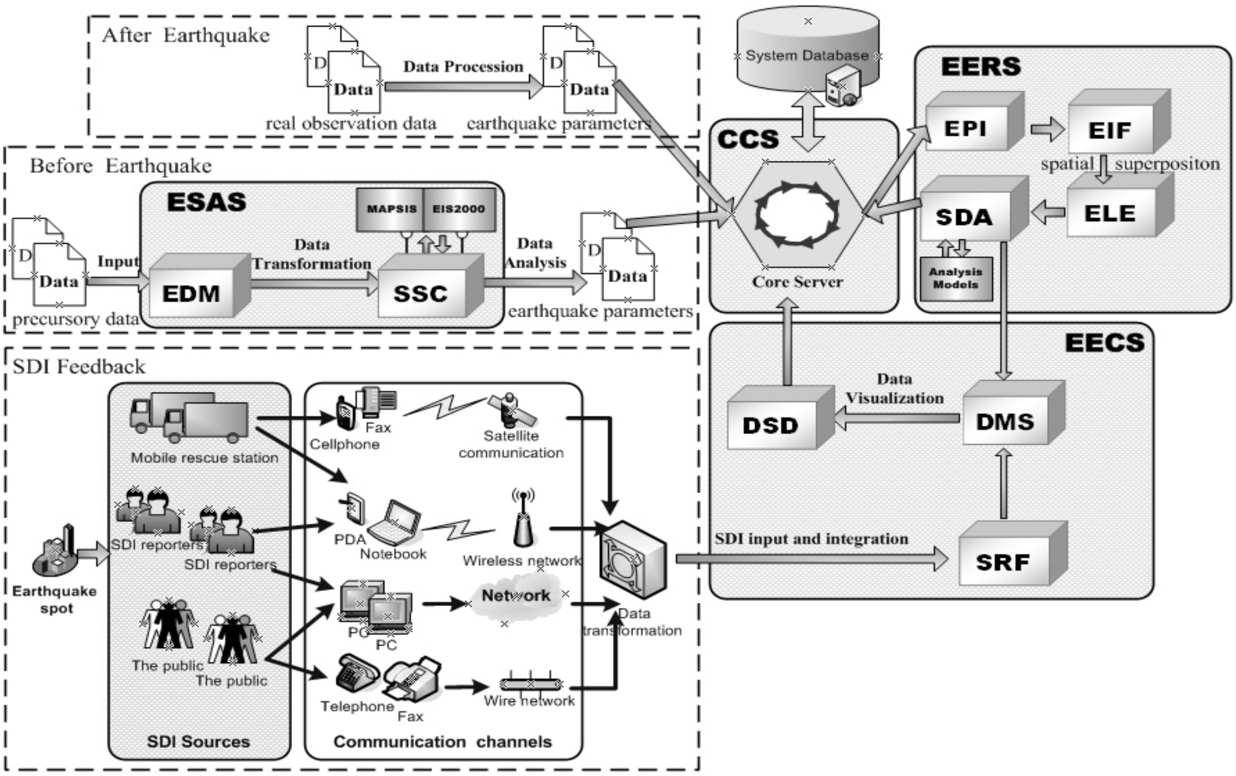

Figure 3 Data flow of UEEMS

5. SYSTEM DATABASE DESIGN

UEEMS is designed for web application and the C/S pattern is adopted. Hereby Oracle 9i DMS is installed on the server as a data application platform of system database to handle all the processions and storages. The system database is logically divided into two parts: the basic database (BD) and resultant database (RD), each of which is further separated into the spatial database (SD) and attribute database (AD) (Gao Jie, et al., 2005; 2006). The BD memorizes the background information and maps of a city and the observation statistics about historical or incoming earthquakes. The RD stores all the calculation data and thematic maps result from modules in UEEMS.
In terms of the data storage in system database, the attribute data are stored with ordinary tables in attribute database. On the other hand, the spatial data have to be memorized with an object-oriented geographical data modeling, called geodatabase, in spatial database. Therefore, the database accessing means (DBAM) are also including two ways:

accessing attribute database by ADO and COM in OLE DB, and accessing spatial database by Arc SDE for Oracle.

6. CASE STUDY

As an important component of EEM informationization, UEEMS has been put into practice in the real emergency command and management of Yuncheng, Shan'xi province. The main functions of UEEMS (English version) described above are demonstrated from Fig.6 to Fig.9 using the data of Yuncheng.

Figure 4 shows the result of emergency level estimation. At the same time, the emergency plan that should be executed and the intensities of each district in a city are also revealed in the same window. Figure 5 shows the earthquake influence field which is composed of some elliptical or round rings representing different ground accelerations and the intensity variation which is expressed with different colors. Figure 6 illuminates the different devastations of important buildings. The severity of devastation is described with various symbols and colors. Figure 7 is a sample-point map which shows the real-time seismic scenarios based on SDI feedback and predicted results. In terms of every SDI sample, there are three colors which describe the development of disaster situation, for instance, red color sample means new disasters; blue color sample means this sort of disaster is under rescue; gray color means the disaster has been eliminated. The rescue requirements are labeled on the map to help commanders to arrange emergency resources and rescue actions.

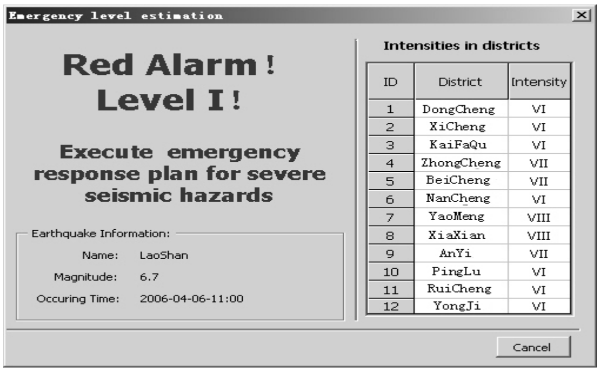

Figure 4 Earthquake emergency level estimation

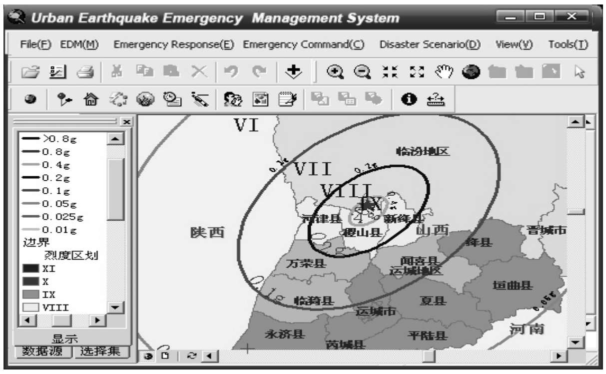

Figure 5 Earthquake influence field

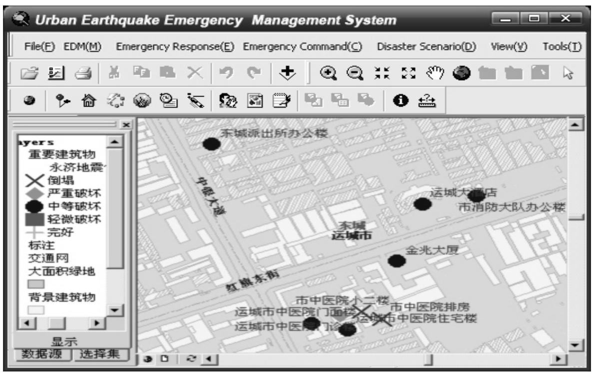

Figure 6 Disaster scenario of important buildings

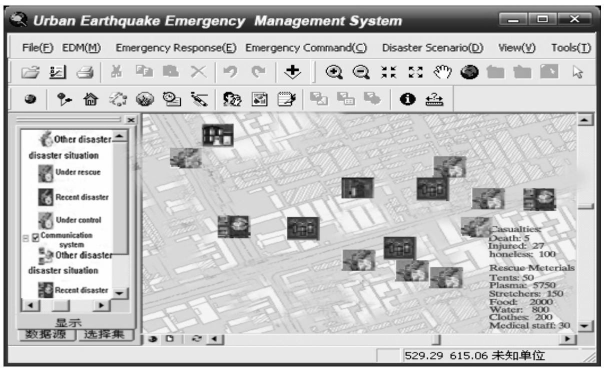

Figure 7 Emergency command map

7. CONCLUSIONS

Urban Earthquake Emergency Management System (UEEMS) is developed in VB program language based on ArcView9.0 and Oracle DBMS. Comparing with the past analogous systems, there are a couple of improvements in UEEMS, such as embedding the mechanism of seismic situation consultation to estimate the parameters of incoming earthquakes, adding the emergency level evaluation, enriching the approaches of SDI feedback, and bettering the visualization of disaster scenarios, rescue requirements, countermeasures and the structure of system database. As shown in the case study, with further optimizations in the environment of software and hardware, UEEMS will play an increasingly significant role in the decision support system for earthquake emergency command and consequently will be helpful to mitigate casualties and economic losses resulting from earthquakes.

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