THE PRELIMINARY DESIGN AND IMPLEMENTATION OF A GLOBAL EARTHQUAKE DISASTER ALERT SYSTEM

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Abstract

This paper describes the preliminary design and Implementation of a global earthquake disaster alert system (GEDAS), including the framework, the database, the computing models and the software modules. The framework of this system is introduced first, including the location of alert in the whole earthquake disaster response process and mainly components of GEDAS. The global scale data used by the system, such as VMAP0, GeoCover and Landscan, is introduced in detail. The core compute models, including scenario earthquake model, economic loss estimation model, casualty estimation model and alert assessment model, are described and analyzed in detail. As to the software, the whole workflow and the function of each model are introduced briefly.

Introduction

Earthquake and earthquake induced disasters, such as the Indian Ocean tsunami in 2004 and the heavily damaged South Asia earthquake in 2005, caused huge economic loss and casualty. Earthquake disasters are becoming the mainly part of catastrophes recently. Although earthquake can not be predicted exactly until now, we can get the magnitude and location for a certain earthquake event quickly after it happened based on the earthquake monitoring network. An earthquake disaster alert system can give a quick estimation of the probable impact and trigger a reasonable emergency response based on the earthquake information and local data and quick response for a disaster event can effectively reduce casualty and economic loss. GDAS Global Disaster Alert System and PAGER (Prompt Assessment of Global Earthquakes for Response) are such alert systems (Martin,2004,2005;USGS,2005). GDAS already gave alert assessment and rich local information to ECHO and UN since 2003 yet PAGER is still in construction.

CISAR (China International Search and Rescue Team), an international disaster aid team, was established in 2001. CISAR took part in the Algeria, Iran and Pakistan earthquake rescue deployments after it was established. From the three deployments, an information support and alert software system is found to be important for quick and effective rescue. In 2005, we started to develop a Global Earthquake Disaster Alert System (GEDAS) for CISAR and the international relief affairs. GEDAS is some kind of GDAS software, such as the base data and alert model used in these systems are same. But earthquake is the only disaster event managed

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in GEDAS and GEDAS give more map making and analysis tools. This paper describes the design and Implementation of GEDAS, including the framework, the base data, the computing models and the software modules.

The Framework of GEDAS

Alert is the first step in the whole disaster information support process. A success alert needs to give economic loss and casualty estimation, disaster trend analysis and emergency response advices after the disaster event as soon as possible. Fig.1 is the picture of the whole information cycle of earthquake emergency response process. The alert must be given in one hour or shorter after the earthquake event to unfold a timely emergency response.

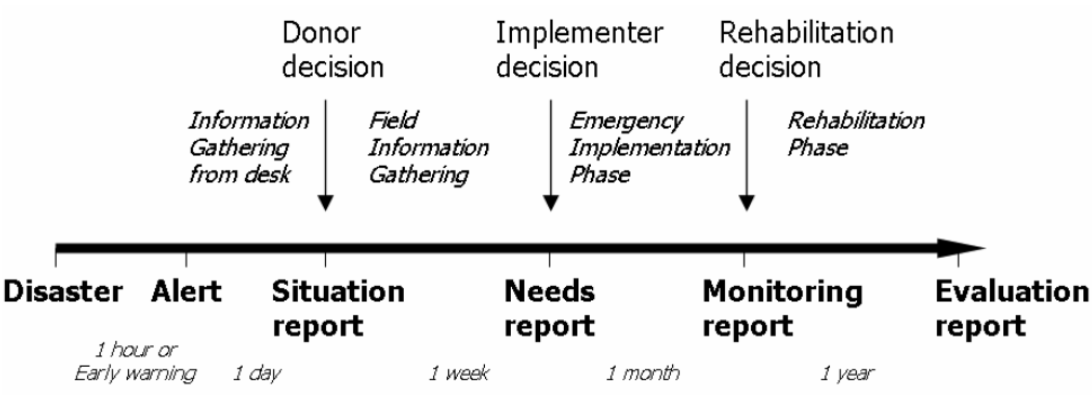

Fig.1 Information cycle of earthquake emergency response process (IPSC, 2005)

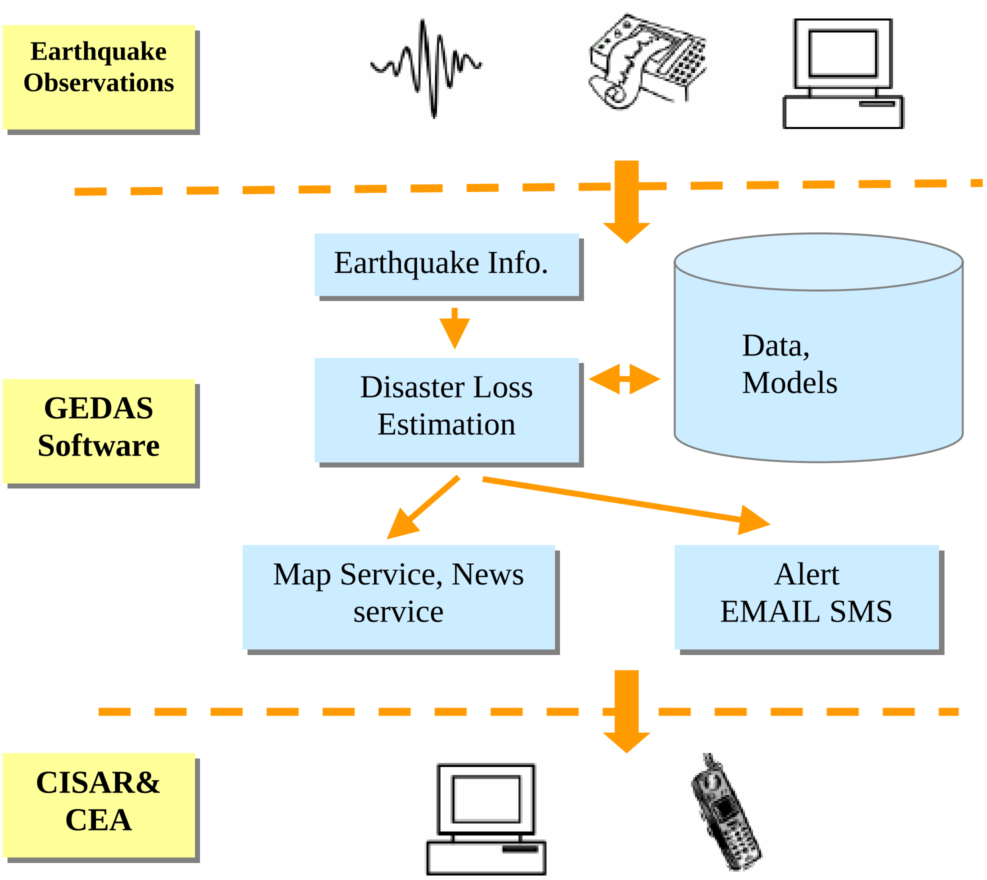

Fig.2 Framework of the global earthquake disaster alert system (GEDAS)

GEDAS composes of three parts, information acquiring, loss estimation and information releasing (Fig.2). Earthquake information can be got directly from monitoring stations and NEIC'S global earthquake list service (Finger). The information processing and loss estimation part is the core of GEDAS. Based on the global database and compute models, GEDAS can give a quick economic loss and casualty estimation and also maps around the epicenter. The alert information is sent to CISAR, NERSS and other related organizations by website, email and SMS.

The GEDAS Database

The Fundamental Geographic Data

1.VMAP0 & VMAP1

Vector Map Level 0 (VMap0) is an updated and improved version of the National Imagery and Mapping Agency's (NIMA) Digital Chart of the World (DCW). VMap0 database provides worldwide coverage of vector-based geospatial data which can be viewed at 1:1,000,000 scale. It consists of geographic, attribute, and textual data. VMap0 includes major road and rail networks, hydrologic drainage systems, utility networks (cross-country pipelines and communication lines), major airports, elevation contours, coastlines, international boundaries and populated places. VMap0 is divided into four parts (Fig.3).

Vector Map Level 1 (VMap1) is based on 1:250,000 map scale source, and is 4 times the resolution of VMAP0. The VMAP1 data is divided into a rather complex global mosaic of 234 geographic zones. However at the present time, NIMA are only releasing 55 selected areas of the VMAP1 dataset. Some of the excuses given include the protection of cartographic monopolies of its overseas partners, such as that it is not ready for the public to see it, that their security office has not approved it, and that NIMA is afraid the public might "misuse" it.

VMAP0 & VMAP1 are read directly into ArcGIS from VPF format and used as the background for loss estimation and map making in GEDAS.

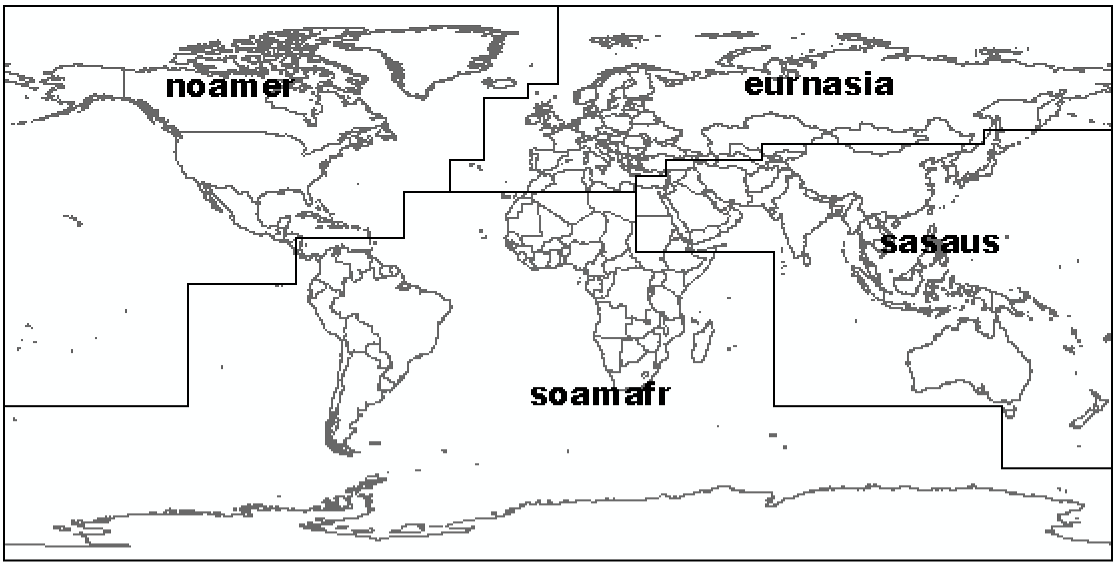

Fig.3 The Tiled Sheets of VMAP0 data

2.GeoCover 2000 Mosaics

The Landsat GeoCover dataset is a collection of high resolution satellite imagery provided in a standardized, orthorectified format, covering the entire land surface of the world (except Antarctica). This is an invaluable record of land cover and land cover change, provided in a consistent manner that allows for use in a wide range of activities including environmental assessment, emergency planning, land management, resource stewardship and many Earth science related research.

The GeoCover 2000 mosaics are segmented into tiles of approximately 250,000 square kilometers. Each tile covers five degrees of latitude in a UTM zone, which is 6 degrees of longitude (Fig.4). The scenes are UTM zone and minimum latitude of the tile and Several tiles of approximately 100-260 MB. These mosaic images are in MrSid format and can be directly opened using ArcView, ArcGIS, ERDAS Imagine, ENVI, PCI or the free MrSid Viewer available from LizardTech.

In GEDAS, GeoCover data are managed by using an index vector layer and used as background for loss estimation and also for map making and 3D visualization.

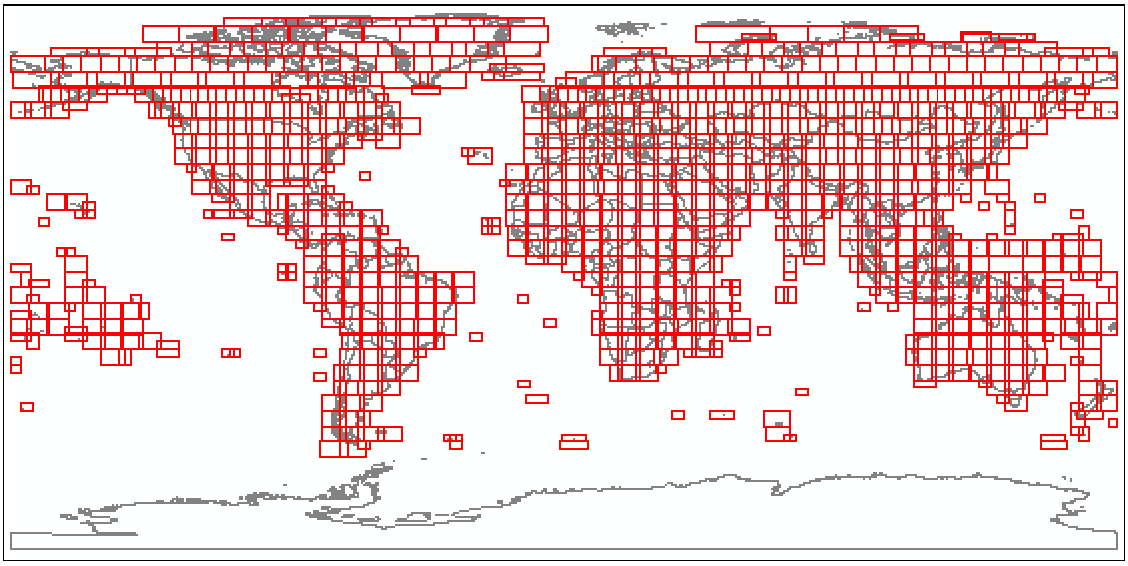

Fig.4 Global distribution of Geocover2000 data

<u>The Population Data</u>

Oak Ridge National Laboratory(ORNL)'s Global Population Project, part of a larger global database effort called LandScan (Fig.5), collects best available census counts (usually at province level) for each country, calculates a probability coefficient for each cell, and applies the coefficients to the census counts which are employed as control totals for appropriate areas (usually provinces).The probability coefficient is based on slope, proximity to roads, land cover, nighttime lights, and an urban density factor. GIS is essential for conflation of diverse input variables, computation of probability coefficients, and allocation of population to cells, and reconciliation of cell totals with aggregate (usually province) control totals. Remote sensing is an essential source of two input variables-land cover and nighttime lights-and one ancillary database-high-resolution panchromatic imagery-used in verification and validation (V&V) of the population model and resulting LandScan database.

Until now, Lanscan is the best population database for disaster estimation. In GEDAS, Landscan is a core database and used as base input for casualty and economic loss estimation.

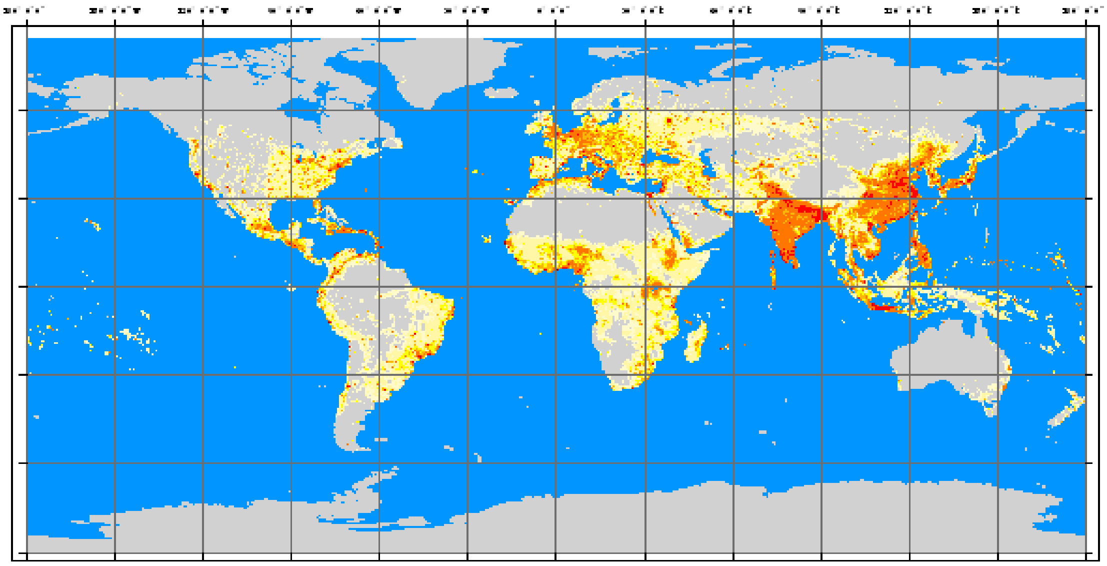

Fig.5 Landscan global population data

Other Data

Other data, Such as SRTM DEM data, GDP data, historical earthquake data, nuclear power station data, are also parts of the GEDAS database, used mainly for 3D Visualization and disaster loss estimation.

Disaster estimation and alert assessment model

Scenario earthquake model

GDAS uses circles which radiuses are 5Km, 25Km, 50Km and 100Km as statistic and analysis region. This method is universal and easy for data summarizing but do not think about the relationship of earthquake intensity and the disaster impact. When we compute the economic loss and casualty, we must know at least a rough intensity for a certain region. We use an empirical relationship to estimate the scenario intensity for an earthquake event. Following is the empirical formula we use in GEDAS which derived from the empirical formula used in Western USA (Anderson, 1978; Howell, 1975; Gupta, 1976; Liu Jie, 1999; Gutenberg, 1956).

$$I = I_0 + 3.2 - 0.00106\, r - 2.7 \lg r$$
$$M = 2/3 * I_0 + 1$$

I_0 is the intensity in the epicenter   M is the Richter Magnitude   r is the radius   I is intensity for a certain distance from the epicenter

In some areas, such as in China, we use more detail empirical intensity relationship to compute earthquake scene.

Economic loss estimation model

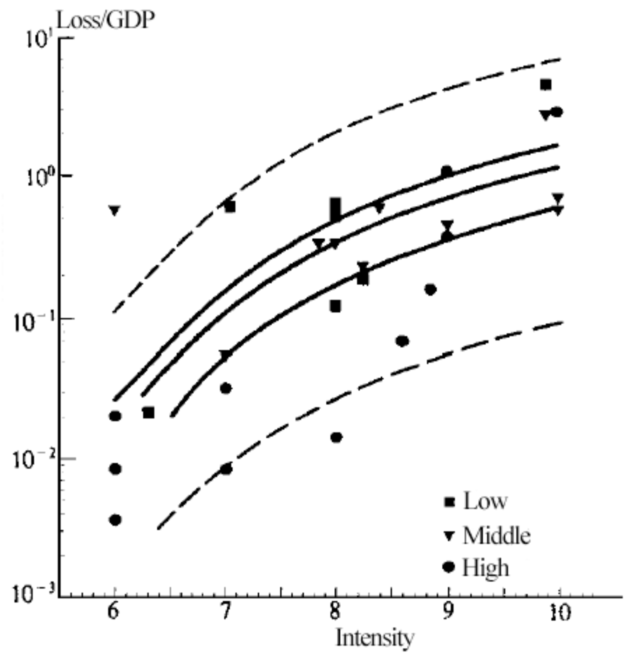

Fig.6 Relationship of earthquake intensity and economic loss (Chen etc., 1997)

We use a method that estimate earthquake losses based on several macroeconomic indices such as the Gross Domestic Product (GDP) and population (Chen Yong, 1995; Chen QF, 1999). This method does not require a detailed inventory database of the structures and facilities in the impact region and can get quick loss estimation.

Fig.6 give us the relationship between intensity and the ratio of economic loss by GDP for Low, middle and high income countries separately. Based on this relationship, we can get the economic loss by using following formula:

$$E_P = \sum_{I_i} P_T(I_i) \cdot f(I_i, \ GDP) \cdot GDP$$

E_P is the economic loss, fI_i, GDPis the ratio of intensity I by GDP, I_I is earthquake intensity, GDP is Gross Domestic Product. P_TI_I is the risk of impact of intensity in T years. For a certain earthquake, P_TI_I is always 1.

Casualty estimation model

Table.1 Matrix of mortality rate and injury rate (Chen Yong, 1995)

Intensity Loss	**Mortality**	**Injury rate**
VI	$0.2 * 10^{-4}$	$0.36 * 10^{-4}$
VII	$3.2 * 10^{-4}$	$3.1 * 10^{-4}$
VIII	$4.0 * 10^{-4}$	$260 * 10^{-4}$
IX	$480 * 10^{-4}$	$2200 * 10^{-4}$

Compare to economic loss estimation, casualty estimation is more difficult. A reasonable relationship between earthquake intensity and casualty must think about the structure parameters. Because we have not a detail structure database until now, a simple relationship for casualty estimation is used in GEDAS (Table 1).

<u>Alert assessment model</u>

Referring to the GDAS alert model, we adopt following alert grade assessment formula:

$$A \quad \max(M - 4.5 \quad 0)^{0.5} \quad \log(\max(P / 80000 \quad 0)) \quad \max(V \quad 0.5)^{1.5} / 3$$

A is the alert score, M is the magnitude, P is the total population in the area where intensity is lager than six, V is the venerability index and can be got from the ECHO global need assessment report every year.

The alert rank can be divided into three kinds, green, yellow and red. When the score value is smaller than 1, green alert will be released; when the score value is between 1 and 2, yellow alert will be released; when the score value is lager than 2, red alert will be released. The international relief organization should concern and prepare for deployment when the red alert is released.

The GDEAS Software

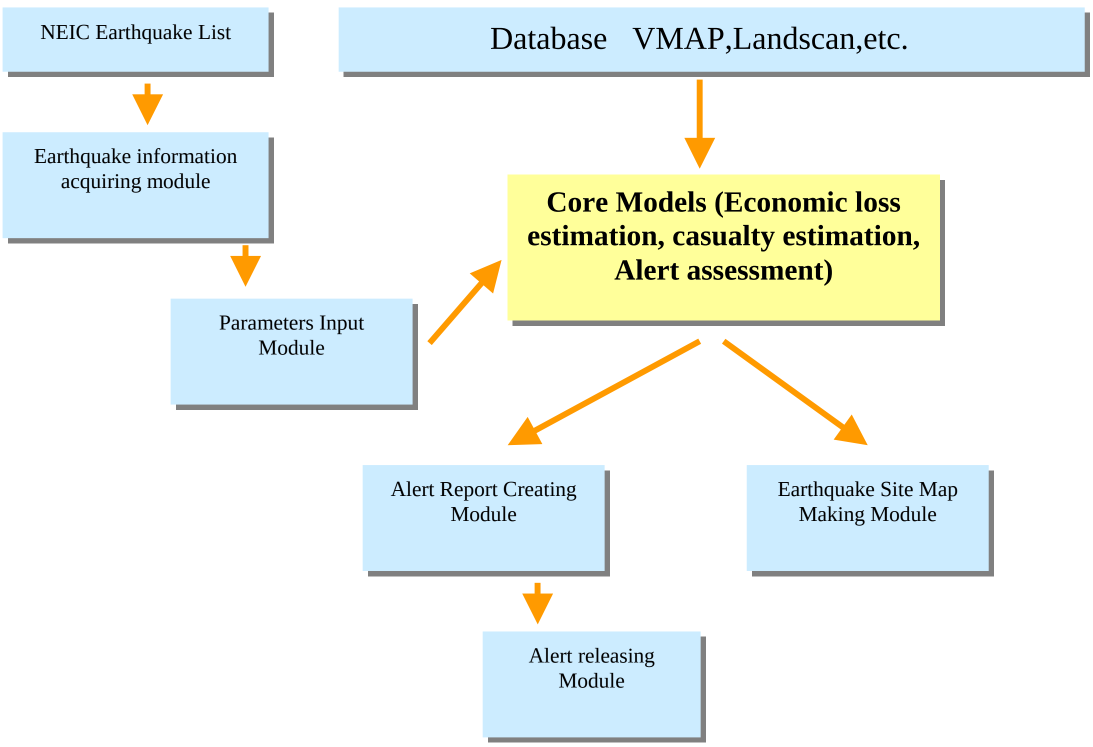

Fig.7 Modules of the global earthquake disaster alert software

The GEDAS software is developed on ArcGIS platform. Fig.7 is the sketch of the modules and the workflow. The software modules includes parameters input module, loss estimation and alert assessment model, alert report creating model, alert releasing module and map making module.

The earthquake information can be got automated or by hand from the NEIC website. The core computing models will compute the earthquake affected field, the economic loss, the casualty and the alert score. The software can create an alert report based on the computed result automatically, including the earthquake parameters, the disaster impact, the trend analysis and the deployment advices. The local maps can also be created for field works (Fig.8).

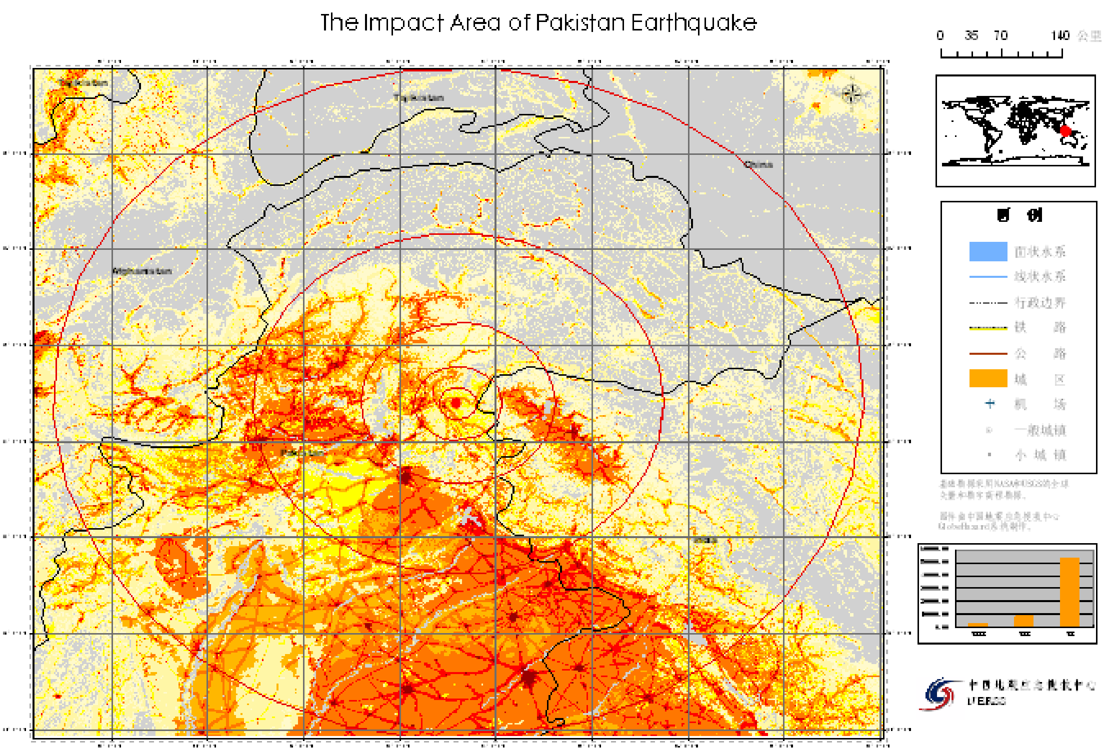

Fig.8 An example of earthquake emergency decision aid map

Conclusion

This paper described the preliminary design of a global earthquake disaster alert system, including the framework, database, computing models and software modules. This software system already supply information and decision support in CISAR's international rescue work. It can also supply information to the international relief community in the future.

The GEDAS software is still in developing, and it can only supply rough economic loss and casualty estimation and simple map making function now. More works, such as the detail assessment models and alert release module are still need to be accomplished.

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