

UNCRD 's 25th Anniversary Commemorative Programme  
**GIS for Disaster Management**

Proceedings  
of the  
9<sup>th</sup> International Research and Training seminar on  
Regional Development Planning for Disaster Prevention

12 December 1996  
Nagoya, Japan

United Nation Centre for Regional Development

UNCRD Proceedings Series No. 18

United Nations Centre for Regional Development (UNCRD)

March 1997

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ISDN : 4—906236—34—0

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## Forword

The United Nations Centre for Regional Development (UNCRD) has been focusing its efforts on the importance of regional development planning for disaster prevention from its inception. With regards to its activities for disaster mitigation, UNCRD has held eight international meetings under the title of International Research and Training Seminar on Regional Development Planning for Disaster Prevention, since 1987. These meetings were held with the participation of invited experts and/or researchers from all over the world where issues on disaster management in developing countries were emphasized as having a vital significance in the coming century. Before the first year of the International Decade for Natural Disaster Reduction (IDNDR), UNCRD has organized the above seminar annually as one of its concrete programmes contributing to the IDNDR.

On 12 December 1996, a technical workshop, the ninth of the series, with the theme of Utilization of GIS for Disaster Management was held in Nagoya organized by UNCRD as a series of seminar on the International Research and Training on Regional Development Planning for Disaster Prevention. The aims of the workshop were to provide scientific and technical information on satellite, strong motion record, and geological data applications in urban seismic risk assessment and management to discuss how to integrate GIS with various kinds of data and sustainable disaster management systems; and to provide hands-on training with the use of computers and training materials.

Several aspects were highlighted in the workshop including: (a) Application of satellite data to risk assessment; (b) Strong motion networks and their application to earthquake disaster management; (c) Development of risk assessment systems; (d) Construction of a GIS; and (e) Disaster and environmental monitoring using GIS technology. The workshop brought together academicians and practitioners from Japan, Mexico, and Mongolia dealing with earthquake prediction, seismic risk assessment and disaster management.

Believing that the knowledge gained through this seminar will be

useful in order to develop a seismic risk assessment and management system UNCRD hereby publishes the report and summary of proceedings of the seminar. The seminar's success was largely due to the active participation of experts, academicians, administrators, and other individuals. Our heartfelt thanks are extended to those who contributed to the preparation of the seminar. Deepest appreciation to paper writers, all participants of seminar, for their sincerest collaboration and hard work in making this seminar a resounding success.

March 1997

Hideki Kaji

Director, UNCRD

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*UNCRD's Anniversary Commemorative Programme*

*10<sup>th</sup> International Research and Training Seminar on Regional Planning for Disaster Prevention,*

*United Nations Centre for Regional Development, 12 December 1996, Nagoya, Japan*

## **Development of the Computer Aided Disaster Management System for Local Governments (CADMaS)**

by

**Yujiro Ogawa**

### **1. Introduction**

#### **1.1 Purposes**

Disaster management for local governments signifies a series of measures which include disaster prevention, emergency response, and recovery and reconstruction. Presumably these measures correspond to the measures described in the regional disaster prevention plan prepared by local governments.

The regional disaster prevention plan describes how each measure operates under specific disaster emergency situations. Based upon the regional disaster prevention plan, local governments take disaster prevention measures before disasters occur. Disaster Prevention Bureau of the National Land Agency and Earthquake Disaster Management Division of the Ministry of Home Affairs take appropriate measures at the national level. At the prefectural level Fire Services & Disaster Prevention Division and Earthquake Preparedness Division take measures, while at the city, town, and village level, each division of the local government undertakes its own measures under the guidance of Disaster Prevention Division. When a disaster occurs, Disaster Countermeasures H.Q. takes emergency measures, and Disaster Countermeasures H.Q. or Recovery H.Q. takes initiatives to guide each division of local governments to carry out recovery measures in the process of reconstruction.

In the above practices of disaster management we found one decisive

defect which was a precious lesson learned from the last Great Hanshin Earthquake. It was the delay of information gathering and the resulting delay of decision making based upon information. It is an urgent task for us to develop a system for quick data gathering and appropriate decision making.

In the process of disaster management, there is a need to decide and translate the measures into action which are to be executed in each stage of disaster prevention, emergency response, and recovery and construction. The data necessary for taking actions has been accumulated by the relevant divisions and made ready for decision making. In most cases, such data is not only voluminous and diversified in its coverage and quality but also transitory in nature therefore, it can be said that the system which simply depends on each division's individual efforts to collect data according to its own needs, does not enable full and appropriate utilization of data required for correct judgment.

Furthermore, as revealed by the Great Hanshin Earthquake, the present practices of collecting data when a disaster occurs are insufficient. Delay of data gathering means delay of emergency measures.

In order to solve the above mentioned problems, the Disaster Management Program of UNCRD is planning to develop a disaster management program assisted by computer and multi-media, which have become commonly used means nowadays.

## **1.2 Institutionalizing local governments disaster management systems**

### **1.2.1 Development of computerized disaster management system**

While choosing some functions in disaster prevention measures which can be computerized, two specific computer-aided disaster management systems to be developed for computerized disaster management.

*System 1:*

This is a system to collect available data beforehand, process it for judgment, and store the output easy to retrieve and understand.

*System 2:*

This is a system of data collection on disaster and of data transmission method.

It is necessary for the system 1 to develop a pilot system according to a specific case, while examining which of the systems, either system 1 or system 2, can be more useful at a certain stage of disaster management. As regard to system 2, it is possible to develop a prototype but actual development of the system should be carried out by local governments; therefore, we would like to identify data requirement for decision making when system 2 is used with system 1.

### **1.2.2 Proposal on data standardization of disaster management system**

As the Great Hanshin Earthquake revealed, disasters would occur in such a scale that with which a single local government alone cannot handle adequately. It is often a case that the government needs to ask help from neighboring local governments and the national government. Because of this need, it would be inefficient for each local government to develop its own computerized disaster management system. If the data is standardized, it would be possible to develop a mutual support system, including disaster management, by sharing data between the local government concerned and its neighboring local governments. Here we will discuss necessary data for disaster management in its details and data standardization for computerized systems including GIS.

### **1.2.3 Development of disaster management training system for local government employees in charge of disaster management**

Since most of the local governments have not experienced a big scale disaster, they would have to cope with a disaster without previous experiences. Because of this, it is important to carry out training on the daily basis, but such a training system for disaster management is not available on hand. Utilizing a disaster management system to be developed by this project, we are also planning to develop a disaster management



training system which simulates an occurrence, gives data collected based in time series, and asks trainees to analyze, and respond according to their judgments.

## **2. Computer-assisted disaster management system**

### **2.1 Three stages of disaster management and their characteristics**

There are three stages in the disaster management; namely prevention, emergency response, and recovery and reconstruction. At the prevention stage we have enough time to implement disaster prevention plan and measures. However, when it comes to the second stage of emergency response, it is crucial to collect information, analyze, and react as quickly as possible. The recovery and reconstruction stage requires the same promptness as the emergency response stage does in the sense it has to cope with the situation quickly, but it has more time to collect information, analyze, and react; therefore, we need to develop a disaster management system which reflects these characters of the respective stages. Accordingly we would like to classify the target fields of disaster management as follows:

1. Disaster management plan formation and its implementation
2. Emergency measures at disaster occurrence
3. Recovery and reconstruction plan formulation and its implementation

### **2.2 System I: Disaster information processing system**

System I manages necessary information (i.e. nature & social information to be obtained beforehand and damage information to be assessed when a disaster occurs) for disaster management process data for analysis, and prepare the output easy to understand.

By planning and implementing a disaster prevention plan, we can draw up damage information based upon previously assessed damages. However it is necessary to enable the persons in charge to use the output and analyze on real time when they implement emergency measures at a disaster occurrence because of the transitory nature of damage information. The same condition can be applied to planning and implementation of a recovery and reconstruction plan. This system includes various subsystems for disaster management.

## **2.3 System 2: Collection and dissemination of damage information**

System 2 is designed to grasp the condition of damage quickly for decision making on emergency measures when a disaster occurs.

## **3. Disaster information processing system**

### **3.1 Basic system for disaster information processing**

There are many things in common in information processing for disaster management although there are diversified in their details for decision making. Things common here are objects for analysis, including facilities, location of manpower and the attribute data, phenomena of disaster occurrences and resulting activities, and routing from one point to another. The following section discusses a basic system of information processing on these.

#### **3.1.1 Extraction system of condition fitted object**

Based upon a basic function of GIS, this system selects a location and its attribute data of necessary facilities and manpower and indicates them on a map. It is also a system to indicate their attributes by the graph and to compute and show a range matching a given condition on the map.

#### **3.1.2 Route selection system**

This is a route selection system which makes emergency transportation of goods and manpower possible from one point to another while avoiding obstacles on the road. This system is an application of network theory and GIS.

### **3.2 Computer-assisted subsystems for disaster management**

This section proposes some possible computer-assisted subsystems for disaster management.

#### **3.2.1 Subsystems to estimate mainly earthquakes and their damages caused by the quake**

Ground Motion Estimation System

Building Damage Estimation System

Fire Risk Estimation System

### **3.2.2 Subsystems to manage emergency measures right after a disaster occurrence**

Affected Area Estimation System

Shelter Selection System

Traffic Facility/Functional Disorder Estimation System

Emergency Surface Transportation Securing System

Distribution System of Emergency Goods to Shelter

### **3.2.3 Subsystems to assist various activities after a disaster occurred**

Emergency medical support system

Educational facility measure/restoration assistance system

Disaster weak support system

Volunteer activity support system

Damaged buildings emergency assessment support system

Damaged housing demolition support system

Temporary housing construction support system

Disaster support related works system

## **4. Damage data gathering and dissemination system**

This system intends to grasp the damage brought by a disaster to make decisions for emergency measures.

At the Great Hanshin Earthquake the delay of grasping damage data caused the delay of early rescue activities, of building up an immediate communication with the Central Government and of getting cOOPeration and assistance from Self Defense Force, and of attending the problem of after math traffic jam. At present collection and dissemination of damage information is the responsibility of the relevant individuals or offices independently, and there is not sufficient cOOPeration among them to share information with each other. It can hardly be said that they utilize currently available communication technology to the extent possible for information sharing both in data collection and dissemination.

### **4.1 Damage information summarization/dissemination system**

This is a system to extract summarize, present, and disseminate information throughout the stages of a damage occurrence form its outbreak

to its termination.

#### **4.2 Quick earthquake damage grasp system by satellite photos**

This is a system to quickly capture damage by satellite photo. We will examine a possibility of grasping a great scale damage in a wide area comprehensively. There is a good chance of applying this system to grasp damage in developing countries and mountainous areas without conducting field surveys.

### **5. Proposal on data of standardization in disaster management system**

#### **5.1 Classification of necessary data for disaster management**

It can be easily guessed that various kinds and quantities of information are needed to deal with three stages of disaster management. If you take a building for example, information is needed for damage assumption, seismic building diagnosis and seismic building retrofit, emergency measures, emergency risk assessment, restoration of damaged building, etc. By classifying these aspects in terms of frequency of data use and then dividing them between basic information and special information, it becomes possible to share the same set of information at various stages of disaster management. It also becomes possible to obtain most recently updated information if it is maintained in a local government's information management system as a part of its urban planning basic information systems.

#### **5.2 Standardization of basic disaster management system**

Data processing will be inefficient when there are incompatible processing systems at the respective subsystems of the computerized disaster management system. The lack of common frame of reference in geographical information systems can be mentioned as one of the typical cases in point.

Since we believe that standardization of the basic system for disaster management is indispensable to facilitate a wide use of local governments' data and systems, we need to examine problems of standardization.

## **6. Development of disaster management system for local government employees**

In order to capacitate the local governments' ability to cope with disaster occurrence, it is important to prepare a disaster management training system for the local officials to practice in the on-the-job environment.

The disaster management system we are planning to develop here provides data of a disaster in the time sequence of its occurrence, asks trainees to analyze the data by themselves, to react according to their decisions made, in other words, we will develop a disaster management training system which simulates process of a decision making by the local government employees in charge of disaster management.

## **7. Conclusion**

It is very important for every country to plan and implement disaster management. The ultimate purpose of disaster management is to prevent loss of people's lives and socio-economic damages of the local society and the nature.

However, there has not been an established disaster management system as such yet. As we have emphasized in this paper, we need to develop a computer-assisted disaster management system and to facilitate capacitation of the local government officials when in charge through a disaster management training system so that they would be able to act most efficiently and appropriately when a disaster occurs.

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*10<sup>th</sup> International Research and Training Seminar on Regional Planning for Disaster Prevention,*

United Nations Centre for Regional Development, 12 December 1996, Nagoya, Japan

## **Evaluation of Damages Caused by Earthquakes Using Satellite Data and its Application to Seismic Disaster Management**

by

**Masaki Murakami**

### **1. Introduction**

Space technologies have brought in potential techniques to monitor and evaluate damages caused by earthquakes for wide areas timely. Techniques that can be employed to obtain geographic information on seismic damages are categorized into two fields: space geodesy and remote sensing. In the field of space geodesy, we determine the location of geographic objects by instruments which receive the signals from the space --- either artificial or natural sources --- on ground. In remote sensing, on the other hand, we use imagery of geographic objects which are taken from the space by sensors on board of satellites. The GPS (Global Positioning System) satellites represents the former while SAR (Synthetic Aperture Radar) and optical imagery by satellites represent the latter. With these technologies on hand, researchers are pursuing efficient and effective ways of data acquisition, particularly in view of time. In this paper, these techniques are explained briefly as well as the activities of the Geographical Survey Institute in this field.

### **2. History of geodetic survey and the utilization of GPS**

Geodetic survey in Japan started more than a century ago for the purpose of topographic mapping. At the first stage, triangulation was employed. The second technique employed in the survey was trilateration with

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electro-magnetic distance meters. The Global Positioning System (GPS) is employed as the third generation technique. At present continuously operated GPS makes the real-time monitoring of crustal movements possible.

The first order triangulation network was established in 1911 after nearly 30 years of hard works using theodolites. The network consists of about 1,000 triangulation stations and the first order triangulation survey had been repeated until 1960's.

In 1970's, electro-magnetic distance meter (EDM) was invented. In 1974, the Geographical Survey Institute (GSI) started the Precise Geodetic Network Survey using EDM. The survey provided us the precise positions of the first and second order triangulation points. The first cycle of the survey was completed in 1984. The survey was repeated for the crustal deformation monitoring up to present.

A new satellite geodetic technique, GPS, has been developed in 1980's by the U S Department of Defense. Though the technique was developed mainly for the military activities, it experimental purpose in 1987. GPS was applied to a part of the second cycle of the Precise Geodetic Network Survey in early 1990's after we confirmed its efficiency and accuracy. Since then, GSI has utilized GPS in many fields of surveying and mapping.

### **3. The establishment of the continuous GPS observation network**

The GPS technology as a surveying tool has matured significantly in the recent decade. GPS receivers have been down-sized and their prices have decreased. Some sets of excellent software have been developed. The precise orbit information of GPS satellites is available through the Internet by the International GPS Service for Geodynamics (IGS).

Carefully designed GPS surveys can achieve the precision of 10 parts per billion (ppb) these days. On these background taken into account, GSI examined a plan of a permanent GPS network throughout Japan for precise geodetic survey and crustal movement monitoring.

Fortunately, the government of Japan approved the budget for GSI to establish an experimental nationwide GPS network in 1993. A hundred and ten (110) stations were installed in the Tokai and southern Kanto areas. The mean distance of neighboring stations is about 15km. Because a big earthquake named 'Tokai Earthquake' has been expected in the areas in the near future, the network has possibility to detect the precursors of the earthquake by daily precise measurements.

The nationwide GPS network was authorized in 1994 as one of the most important projects in the institute's long term basic plan. The purpose is the establishment of a new type of geodetic control network and the regional tectonic movement monitoring with daily data. A hundred (100) stations were installed throughout Japan in this year. The mean distance between neighboring stations is about 120km, which is more sparse than that in the Tokai and southern Kanto areas.

In 1995, four hundred (400) stations were added to this network and all 610 stations were integrated to one system, and GSI is installing additional 250 stations, which results in the mean distance between neighboring stations of 15-20 km all over Japan. At the end of March, 1997, GSI will operate the GPS network which consists of about 900 stations.

The network revealed from only one year observation the deformations of Japan due to tectonic motions (Figure I ), which had not been clearer from the data obtained by conventional geodetic techniques.

#### **4. Examples of crustal deformation detected by the network**

Within its first four month operation, the nationwide GPS network experienced three major earthquakes that exceed Magnitude 7. They were:

- a) Hokkaido-Toho-Okai earthquake (M8.1) on October 4, 1994,
  - b) Sanriku-Haruka-Okai earthquake (M7.5) on December 29, 1994, and
  - c) Hyogo-ken Nanbu (Kobe) earthquake (M7.2) on January 17, 1995.
- (see Figures 2 and 3)



Grapes VELOCITY 1995/1/18 - 1995/12/31  
(with respect to Tsukuba IGS station)  
Scale: 50 mm/year  
250 Kilometers

**Figure I Crustal deformation of Japan observed by the nationwide GPS network**

In each case, the GPS stations survived and provided us the information on wide area coseismic displacement that was essential for constraining fault parameter models.

Figure 2 show's the displacement vectors in Hokkaido-Toho-Oki earthquake (above) and Hyogo-ken Nanbu earthquake (below) detected by the GPS network. In the former earthquake, the Nemuro station which located about 170km west of the epicenter moved 44cm to the east. In the latter, stations 50km east or west of the epicenter moved toward it by 4cm west or east.

Figure 3 shows a displacement map in Sanriku-Haruka-Oki earthquake where the KuJi station recorded the largest coseismic displacement of 8 cm toward the epicenter. The GPS observation of this earthquake received a great attention because it showed gradual crustation deformation continuing for 10 days after the main shock (Figure 4). This is the first case where postseismic deformation without seismic waves were observed.

**Figure 2 Coseismic displacement of GPS stations caused by the 1994 Hokkaido-Toho-Oki earthquake (above) and the 1995 Hvogoken-Nanbu earthquake (below)**

In 1996, the network detected crustal deformation with no earthquake in the Boso Peninsula. It is said that this phenomenon is caused by a 'silent' earthquake. This is a great fruit of continuous GPS observation.

These observations provide much more information than ever before on damages caused by earthquakes, which give a leap in the field of the researches.

## **5. Crustal deformation detected by SAR interferometry**

Synthetic Aperture Radar (SAR) is a new technique in remote sensing by which ground objects are observed remotely with sensors on board of satellites or airplane. As the name depicts the nature of the technique, SAR employs microwave radar that is emitted to targets on ground and reflected from them. Analysis of reflected microwaves gives information about the characteristics of land such as surface topography and subsurface structure.

**3 Coseismic displacements caused by the 1994 Sanriku - Haruka - Oki earthquake**

**Figure 4 A time series of the Kuji-Rifu baseline, taken every 75 minutes, in the events of the 1994 Sanriku-Haruka-Oki earthquake. A postseismic slow deformation is seen after a rapid coseismic deformation**

To obtain higher spatial resolution, the aperture, namely the size of radar antenna, should be larger. However, ten centimeter resolution requires the aperture of, for instance, one kilometer, which is not a realistic size for the satellite borne sensors. Instead, signals from a flying object -- a satellite in our case --- are synthesized along its orbit to make a virtually large aperture of antenna. SAR also employs wave modulation technique to obtain higher resolution along the line perpendicular to the orbit. These two techniques give us 20-m spatial resolution in case of the satellite JERS-1 launched by National Space Development Agency (NASDA) in 1992.

In SAR interferometry, we use two image data taken for the same area at deferent epochs. If the one image is taken before an earthquake and the other after it, these two image data have different information about

surface topography because the shape of the ground surface is deformed by the earthquake. Extracting differences in information about surface topography between these two images --- the process is called interferometry ---, we can measure the deformation of ground surface caused by an earthquake. Amazingly, surface deformations of the amount of a few centimeters can be detected from the space using this technology. Information about surface deformations are visualized as a fringe pattern image, which is called interferogram (Figure 5). Areas in a fringe belt with a certain brightness have the same amount of deformation: that is, a fringe belt in a interferogram corresponds to a contour line in a map. A contour line indicates areas that have the same elevation; A fringe belt indicates areas that have the same deformation.

We have made analyses of seismic deformations in several areas using SAR interferometry collaborating with NASDA and Jet Propulsion Laboratory (JPL). We show two examples in the following section.

### **5.1 The 1995 Hyogo-ken Nanbu earthquake**

Large crustal movements were caused by the fault motion of the disastrous earthquake around Kobe and Awaji. The deformations were observed by GPS as mentioned above. Though the GPS network brought in new ideas on earthquake researches, the spatial distribution of

**Figure 5 SAR measures the distances between the satellite antenna and a target on ground surface before and after an earthquake. Crustal deformation due to the earthquake is derived from these measurements and visualized as interferometric fringe pattern**

observed points was as sparse as 50 km. SAR interferometry from JERS-1

data revealed the deformation around the fault with spatially dense distribution of the data (upper of Figure 6). The fault motion can be interpreted from this interferogram as a right-lateral, strike-slip fault.

## **5.2 The 1995 Neftegorsk earthquake**

A large ( $M_w=7.0$ ) earthquake occurred on May 27, 1995 at the northern part of Sakhalin Island. Field workers reported a right-lateral, strike-slip seismic fault as long as 35km, with the maximum lateral displacement being about 8.1m.

We obtained reasonably good interferogram from JERS-1/SAR data which shows, in this case, mainly vertical displacements of the area (lower of Figure 6).

The resulting interferograms show characteristic fringes. First, around eastern side of the southern end of the seismic fault the uplift with a pair of adjacent peaks clearly appears, northern one of which is as large as 70 cm. Second, eastern side of the north end of the fault subsided about 1m. Other observation techniques could not reveal them because of unevenly distributed data --- for example, sparse GPS observation data. Our study shows that SAR interferometry is a unique geodetic tool to obtain spatially dense information which could not be obtained by other techniques.

Figure 6 Crustal deformations detected by Synthetic Aperture Radar (SAR) Interferometry in Kobe-Awaji region (the 1995 Hyogoken-Nanbu earthquake) (left) and in northern Sakhalin (the 1995 Nefchegorsk earthquake) (right)

## **6. High-resolution satellite imagery**

Satellite imagery has been playing an important role to provide information on natural resources, land cover, water distribution, cloud

distribution as such. Spatial resolution of several tens meters are sufficient for these purposes. Recently, satellite imagery with ten meter resolutions, such as the imagery taken by SPOT satellite, can be used to compile or update maps of medium to small scale (1/50,000 or smaller). However, owing to the diversion of military technologies to public use after Cold War, satellite imagery with resolution as high as one meter will be commercially available in the near future. Using these satellite data, we may identify damaged area from block to block, or even from building to building, from the space right after an earthquake. Some simulations were made to confirm the ability of high resolution satellite imagery, though the further research will be needed before practical use of the data. Table 1 shows launched plans of high resolution satellite imagery by three companies. EARTHWATCH announced that observed points was as sparse as 50 km. SAR interferometry from JERS-1 data revealed the deformation around the fault with spatially dense distribution of the data (upper of Figure 6). The fault motion can be interpreted from this interferogram as a right-lateral, strike-slip fault. The data from their satellite EarlyBird with 3m resolution will be distributed early in 1997.

**Table 1 High-resolution satellite imagery commercially available in the near future**

## **7. The coordinate transformation**

The GPS system refers to WGS84 or ITRF (IERS Terrestrial Reference Frame) Many other data from satellites also refers to global geodetic coordinate systems. On the other hand, each country in the world defines its own national geodetic coordinate system for surveying and mapping. National coordinate systems, from which latitude, longitude, and height of a certain point in a country is derived, differ from country to country. This means that the location of a border between two countries may be described in different latitude, longitude, and height by the two. When we use GPS or other satellite data for surveying and mapping, coordinate transformation between global and national (or regional) geodetic systems

should be applied.

GSI uses a unique transformation method shown in the following.

First, a new datum, the Tsukuba Datum of 1992, was established using four VLBI (Very Long Baseline Interferometry) baselines and 2,912 control points of the Primary Precise Geodetic Network of Japan to modify the distortion of the existing datum, Tokyo Datum. The precision of the coordinates was better than 20 cm for all stations. Then we investigated and determined the relationships among Tokyo Datum, the WGS 84 coordinate system, and the ITRF coordinate system using Tsukuba Datum of 1992.

Second, we produced the correction vectors for the position in Tokyo Datum to that in the Tsukuba Datum of 1992. We found typical correction vectors, 8.5 m in Hokkaido, 5.4 m in San'in, and 4.4 m in Kyushu. The comparisons of spatial distances of Tokyo Datum with those of VLBI baselines show that the scale errors are  $-1.2$  to  $-4.1$  and  $+3.6$  in northeast Japan and western Japan, respectively.

Third, we computed the regional coordinate transformation parameters for high-accuracy GPS measurements. We employ multiple regional transformation parameters to improve the accuracy of practical coordinate transformations because a general parameter model cannot represent the local distortions of the existing geodetic network. The parameters are derived in terms of differences in latitude, longitude, and height for each region of 40 arcmin in latitude by 60 arcmin in longitude. Thus we have determined and provided the station coordinate set and transformation parameters that are essential to achieve 0.1 ppm accuracy in GPS relative measurements in Japan.

## **8. Concluding remarks**

Space geodesy and remote sensing are potential tools for monitoring and evaluating seismic damages. Those techniques have already been applied and indicated their capability for the practical use in future. However, we should not expect too much about these technologies right now because of the present limitation of data availability as well as the cost of data

acquisition. In addition, geodetic coordinate systems should always be taken into account when one uses satellite data. With these in mind, research works should be promoted toward applications of data from the space technologies to practical use.



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*10<sup>th</sup> International Research and Training Seminar on Regional Planning for Disaster Prevention,*

United Nations Centre for Regional Development, 12 December 1996, Nagoya, Japan

## **Analysis on Damage Areas of the Great Hanshin - Awaji Earthquake by Using GIS**

by

**Bambang Rudyanto \***

**Eiichi Itoigawa\* \***

### **Abstract**

The Great Hanshin - Awaji Earthquake magnitude with 7.2 on the Richer scale abruptly occurred breaking the silence of the early morning of 17 January 1995. More than 5,000 people living in Kobe were crushed to death. Considering that this huge disaster struck Japan, which consider itself to be a 'Developed Country', reminds us that GIS is needed in every place in the world. By using GIS, Wide Damage Areas like Hanshin can be observed quickly and the method can be standardized. Also data stored can be retrieved at anytime. But some problems are still exist, and those solution have to be found. The purpose of this paper is to evaluate the impact from the Great Hanshin-Awaji Earthquake by using GIS, in order to build a Disaster Management System in the near future. This will be useful to minimize the casualties from natural disasters and to facilitate a quick response from the government in the event of such natural disasters.

### **1. Target area**

Japan has 47 Prefectures ('Ken' in Japanese). Prefectures are composed of Cities ('Shi'), Towns ('Cho') and Villages ('Mura'). Major Cities are further divided into Wards ('Ku') for administrative purposes. The Hanshin (Kobe-Osaka) Metropolitan Area, together with the neighboring city of Kyoto and its vicinity forms the Kansai or Keihanshin Metropolitan Area, which is the second largest metropolitan area in Japan. The earthquake violently shook the cities of Kobe, Akashi, Ashiya, Amagasaki,

Itami, Kawanishi, Miki, Nishinomiya, Takarazuka, Sumoto and the northern half of Awaji Island in Hyogo Prefecture, and the cities of Osaka, Ikeda, Suita, Toyonaka and Minoo in Osaka Prefecture. The earthquake occurred at 5:46 a m on January 17, 1995. The epicenter, at 34.36 degree north and 135.00 degree east, with a depth of 14 km, was located on the northern tip of Awaji Island, approximately 20 km southwest of the central business district of Kobe City. The magnitude was computed at 7.2 on the Richer scale.

The City of Kobe, which was most severely shaken, has a population of 1.5 million, The average population density of the City of Kobe is 2,779 per sq. km and 64.5% of the population (979,000 people) live in densely populated area of more than 5,000 persons per sq. km. The target area of this research (Figure 1) are concentrated on the city areas of Kobe (Excluding West and North ward), Amagasaki, Nishinomiya, Ashiya, Itami, Takarazuka and Kawanishi. The total area covered is 460 km<sup>2</sup> with has population of 2.5 million.

### Figure 1 Target area

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## **2. Base Map Data**

Base map data of target area were collected from Geographical Survey Institute of Japan (GSI) which has scale of 1:10,000. This is a digital map without vector data of the buildings and excluding the Awaji island. Vector data of the buildings are only available in the scale of 1:2,500, thus we used this GSI map for the detailed of analysis. But the covered map was partly available, especially only for the city of Kobe. The other vector data of the buildings were created from paper map which had a scale of 1:2,500. Finally, the total vector data of the buildings reached a number of 559,400. We used this detailed data to analyze the damage impact from the earthquake by using GIS (Geographic Information System).

## **3. Comparison of the data before and after damage**

### **3.1 Data before damage**

With the basic data of 1:2,500 scale, the data of the city before damage could be determined its height and structure. For this category there were 3 types of buildings. First is those which had more than 3 floors, usually made of RC or SRC. Then, the buildings which had 1 or 2 floors, usually made of wood. The last is the buildings which were defined by no walls. This type included garages, stations, etc.

Another very helpful data was the City Planning Investigation Map in 1990. This investigation is usually repeated in every 5 years. The way to mark the investigation result can be explained by "An orthodox GIS", in which the difference between buildings are colored by pencils. After checking and cleaning the data manually, those data are changed into "A modern GIS", which are entered into the computer. Those data captured 80-90% totally could be analyzed automatically.

### **3.2 Data after damage**

The data for the condition of most of the buildings after the earthquake were gathered from the survey conducted by the voluntary students of Architectural Institute of Japan and by City Planning Institute of Japan. The other areas from Amagasaki, Itami to Kawanishi were surveyed by the Hyogo Prefecture Residential Planning Division. As a result, 442,618 of the buildings were identified. This data covered 79.1% of the total

area.

To determine the condition of the buildings we used some data from many sources. Some of the buildings were in the assessment of "Usage Prohibit" made by Ministry of Construction which covered Kobe and Nishinomiya. The buildings which had more than 4 floors were in this category, and there were 919 buildings in Kobe City, 500 buildings in Nishinomiya City. Another source was the buildings which had emergency risk assessment. These were the result of a survey conducted by the Committee of Earthquake for Damaged Buildings. The standard for this category is the apartment buildings having more than 2 floors, and declared dangerous in Hyogo and Osaka Prefecture. There were about 46,000 buildings in this category. The explanation of those Integrated Data Base on GIS can be sorted as shown in the Figure 2.

### **Figure 2 Integrated data base on GIS**

#### **4. Damage analysis**

The calculation base for this analysis consists of the number of buildings, and which area the building is situated. This area is calculated on digital map. The Data Base of the buildings are stored in ID for each building in vector line. The codes are mainly used to determine 3 categories of buildings. The first category is by height/structure, which has 4 elements; Low Story Buildings, Middle/High Story Buildings, Buildings with no walls and Unidentified Buildings. The second category is by the usage of the buildings, which have 6 elements; Detached Houses, Apartment Houses, Commercial and Office Buildings, Industry Buildings and Warehouses, Others and Unknown. The third category is the Damaged Buildings, which has 6 elements; Collapsed, Damaged, Slightly Damaged, No Damage Found, Destroyed by Fire and Unknown. Based on these 3 categories, we analyzed the impact from the earthquake for each building.

Analysis on damage area is based on polygons for each unit. There are 3 types of polygons as a unit for the analysis. They were all created from the GSI-10000 data. The City Polygons and the Address Code (Chocho-me) Polygons Unit are both created from the administration division by the

government. The Block Polygons Unit are created from roads, waterlines and also from the governmental boundaries.

#### **4.1 Damage to structure/ type of the buildings**

On Figure 3 shows that Low Story Buildings have a higher risk than Middle/High Buildings. Nearly 200,000 buildings have damaged slightly, middle damaged or collapsed. In total, the number of buildings destroyed by fire were not so much, but the risk of fire became greater as the buildings got higher (Figure 4). On the figure of component ratio (Figure 5), the percentage of Low Story Buildings which were damaged are about 40%, including nearly 10% of collapsed buildings. While the Middle/High Story Buildings which were damaged reached 30%. Without calculating unknown data, it could be predicted that half of the total buildings were damaged. Further, the Low Story Buildings and the Middle/High Story Buildings were analyzed on the level of the damage for its type and location.

**Figure 3 Damage analysis (Structure damage)**

**Figure 4 Damage analysis (Low story building)**

##### **4.1.1 Damage to low story type buildings**

Among the type of the buildings, the detached houses had the most number of damage from the earthquake, and it was followed by Apartment Houses. Commercial-Office Buildings and Industry Buildings-Warehouse. But the ratio of collapsed Apartment Houses had the highest risk. The apartment houses had the highest potential to be damaged by the earthquake.

Figure 6 shows the location of the Damaged Low Story Buildings, where Nishinomiya City is the most disastrous area. Amagasaki City came second, and Nagata Ward was the third. In Nagata Ward fire destroyed many buildings more than in any other areas.

**Figure 6 Damage analysis**

##### **4.1.2 Damage to middle/high story type buildings**

Usually a house which has more than 2 floors is rare, so it is predictable that Apartment Houses are the type of houses which would be damaged mostly among Middle/High Story Buildings. The risk to be burned is higher from the taller building.

Figure 7 shows the location of the Damaged Middle/High Story Buildings, where Chuo Ward was first, Hyogo Ward was second, and Nagata Ward was the third rank of the disastrous places for Middle/High Story Buildings. Again, Nagata Ward led the number of the disastrous place by fire comparing to any other areas.

#### **Figure 7 Damage analysis (Middle/High story buildings)**

#### **4.2 Spatial distribution of collapsed ratio of buildings**

Figure 8 is the typical GIS result in which the Spatial Distribution of the specific cases are visible. This kind of spatial distribution is necessary for the purpose of further assessment. Figure 9 shows that the older buildings had higher risk of collapsing than the new ones. One dot in the figure represents one Town (Cho). The correlation coefficient between Ratio of Building Number Constructed Before 1980 and Ratio of Collapsed Building Number is 1.3864.

#### **Figure 8 Damage analysis (Structure damage)**

#### **Figure 9 Damage analysis (Structure damage)**

#### **4.3 Spatial distribution of fire damage**

As shown on the Figure 10, the distribution of Fires following the Earthquake mainly exist along the alluvial belt. This figure shows that the fires damaged the buildings along the places where the earthquake occurred.

#### **Figure 10 Damage analysis (Fire damage)**

If the ratio of wood in the building gets higher, the risk to get damaged from the fire will be higher (Figure 11). And the taller the building

is, the bigger the risk will be too (Figure 12). Figure 13 shows the correlation between scale of fires and the Structural Damage of Buildings.

Scale of Fires and Urban Structure

Scale of Fires and Urban Structure

**Figure 11 Damage analysis  
(Fire damage)**

**Figure 12 Damage analysis  
(Fire damage)**

## **5. Problems in the development of disaster management system**

### **5.1 Data storage problems**

The biggest problem in Data Storage was that the governmental office buildings were also damaged in the earthquake. The maps and other important city planning materials were dispersed in the warehouse, or buried under the collapsed buildings. As a result of the damaged buildings, the computer had also in collapsed, and the data could not be extracted. The collected materials were in disorder, and took too much time to reorganize.

To solve those problems, we propose some counterplans. First, the governmental buildings should be built with base isolated structures. Second, the data should be kept in the different places. Third, the organization in a different place should be ready to grasp and analyze the damage in case of emergency

**Figure 13 Damage analysis (Fire damage)**

### **5.2 Map data problems**

The main problems in the data of the building was that the apartment was treated as one building, but actually it had many dwelling records in it which is not linked currently. Another problem is when the detached house had extension, it was treated as two buildings. So, a better data is that the building polygons should be stored in a map with a scale better than 1:1,000.

### **5.3 Digital map problems for GIS**

Actually no standard on digital data of the buildings. For example

the Kobe Digital Map which had a scale of 1:2,500 was just a collection of open lines. There were also many unnecessary data in GSI-1000 digital map. If the two different scale maps are overlaid, then the buildings will not fit in the same block (Figure 14).

#### **Figure 14 Digital map for GIS (Overlay problem)**

#### **5.4 Generic data problems**

Population and other textual data usually based on address, and not on geographical location. Even on address itself, the code polygon is maybe the smallest textual information, but this seems still too large for the city planning.

We conclude from this problem that the actual position of the building is more important than just an address. One of the reasons is that the residents and the building types are completely different along wide roads, compared to the small roads. One of the resolutions to get the actual position of the building is by linking geographical position to these textual information. To achieve this aim, the building permission forms, the road construction drawings, and other infrastructural data must be changed from paper to digital data.

#### **5.5 Investigation/ground truth problems**

Because the ID numbering method of the buildings were not organized, it will be difficult to check with the actual data of the buildings. The data format is also different depending on the institution which organizes it. The input format, and input data had to be rechecked. Even the investigator itself sometimes is not familiar with the place of investigation. After the investigation, the hand carried map is usually heavily disorted.

To solve this problem we suggest to bring the portable computers with GPS for investigation (Figure 15, Figure 16). The data from each portable computer will be sent to the computer server with help from GPS to recognize the position. This system, Intelligent Field Note with GPS, is necessary to get the data in the real time, so that the assessment will be organized quickly.



**Figure 15 Intelligent field note  
with GPS**

**Figure 16 Intelligent field note  
with GPS**

### **5.6 Data conversion problems**

An experiment by University of Kyoto proved that from 9,300 points, 682 points (7.3%) are unmatched, and 822 points (8.8%) are duplicated data. Also, the creation date of the maps used in both systems were different. The accuracy of the maps itself were different. This research also proved that the town house data were treated differently. It may be derived from this problem that the format is different from one another. So it is better that the map information transfer format be organized.

### **5.7 Calculation unit problems**

The blocks should be a basic data for the future digital maps, because it is an important unit for city planning. But in the real data now, the polygon of the building sometimes lie across governmental boundary polygons.

## **6. Conclusion**

The digital map basically from vector data of each building in Kobe had been analyzed. The number of the buildings in the digital map is more than half of a million. The data of each building contains 3 categories: a structure, height and the type of damage such as collapsed or destroyed by fire. It is also accessed to the other data base, which is able to show how many victims are in the building, including the name and age of the person. GIS for the disaster is necessary to minimize the casualties from the natural disasters and to facilitate a quick response from the government in the event of such natural disasters.

But for developing countries, to digitize all houses in one area is almost impossible. Due to a lack of housing map, a huge data storage and the cost of those computers is too expensive compared with the daily cost of living are the reasons why it is difficult to build a GIS system. The solution is that in some countries, it is better to wait for the Satellite Data which has resolution less than 1 m such as from Quick Bird, with less cost to purchase, because with only a resolution less than 1 m we can digitize a building. This

technology is what will be referred as 'A Remote GIS', a mixed name of Remote Sensing and GIS.

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*UNCRD's Anniversary Commemorative Programme*

*10<sup>th</sup> International Research and Training Seminar on Regional Planning for Disaster Prevention,*

United Nations Centre for Regional Development, 12 December 1996, Nagoya, Japan

**Construction of Strong Ground Motion Network  
and  
its Application to Seismic Disaster Management**

by

**Shigeo Kinoshita**

**1. Introduction**

After the Kobe (Hyogoken-nambu) Earthquake 1995, the Japanese government decided as an action program in 1995 to build up the strong-motion observation network and to release future strong-motion records as soon as possible. The National Research Institute for Earth Science and Disaster Prevention (NIED), Science and Technology Agency, put the program into practice at once.

*Kyoshin Net* (K-NET) is a product yielded from this one-year program. The K-NET is a system which sends strong-motion data on the Internet, data which are obtained from 1,000 observatories deployed all over Japan. The K-NET was constructed on the basis of three policies. (1) The first is to do a systematic observation. The K-NET uses the same seismograph, K-NET 95, and installs it at free field sites. (2) The second is to make a uniform network. The K-NET consists of observatories having an almost equal station to station distance. Also, the K-NET is a distributed seismograph network. The distributed seismograph network give each seismograph a uniform chance of triggering independently. Distributed seismograph networks may be more reliable than centralized networks. (3) The third is complete release of strong-motion records on the Internet. These open data include the soil structures of all sites, obtained by downhole measurement.

We believe that the information obtained from the K-NET without any restrictions may be used not only before and long after a shock but also immediately after a shock, and will contribute to earthquake disaster mitigation in various fields.

## **2. K-NET**

### **2.1 Observation network**

The K-NET consists of 1,000 strong-motion observation stations and a control center. Figure F shows the distribution of K-NET stations. The average station to station distance is about 25 km. This spacing of observation sites can sample the epicentral region of an earthquake with a magnitude of 7 anywhere in Japan.

Each observatory is installed on a site 3 meters square. It commonly consists of a house made of fiber reinforced plastic (FRP), a concrete base on which a strong-motion seismograph is installed, facilities for electric power, a telephone line with lightning arresters, and a fence. The house is designed

#### **Figure 1 Distribution of K-Net stations**

to withstand snow of 4 meters depth. Figure 2 shows the layout of observatory. At sites where the temperature becomes less than -20 degree C, the base is constructed about 80cm below the ground surface as shown in Figure 2. Thus, the K-NET may offer a uniform free field strong-motion data set.

#### **Figure 2 Layout of observatory**

The headquarters of the K-NET is the control center in Tsukuba city. The control center fully monitors the seismographs, acquires the strong-motion data from K-NET95 by telemetry, and makes the database on strong-motion data files and earthquake catalogs. The procedure of data retrieving is as follows. After receiving the prompt source parameters, i.e.,

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the epicenter, depth and magnitude of an earthquake, determined by JMA (Japan Meteorological Agency), the control center automatically estimates the distribution of maximum acceleration by using an empirical function relating maximum acceleration to magnitude and distance (Fukushima and Tanaka, 1990), and then starts to retrieve the strong-motion records on basis of the estimated maximum acceleration map. The K-NET95 has two RS232C ports. The control center usually occupies one of the two and communicates with the K-NET95 by a dial-up procedure. The communication rate is automatically determined by the line condition. The maximum rate is 9,600bit/s. The communication protocol is based on AT commands.

The other RS232C port is connected with a local government. The local government may be able to obtain the strong-motion data more quickly than the control center and retrieve the data from the K-NET95 at the site if AC power is lost and the telephone line is disconnected. This compensates for the control center's dependence on possibly unreliable telephone telemetry.

The K-NET95 continuously maintains a monitor file which has information on the state-of-health of the seismograph. The control center regularly checks these monitor files in order to maintain the K-NET. When the control center finds abnormal data in a monitor file, the center orders a specific maintenance company to repair the seismograph.

The control center makes a database of strong-motion records obtained from the K-NET95 seismographs. Simultaneously, the database of earthquake catalogs and station histories are made. These databases are maintained on a database server with a memory of 120GB which is installed in the control center.

## **2.2 Instrumentation-type K-NET 95 seismograph**

The strong-motion seismograph, type K-NET95 manufactured by Akashi Co., is an accelerograph with wide frequency-band and wide dynamic range. The K-NET95 has the following specifications :

### 2.2.1 Sensor

The sensor, type V403BT, is a triaxial force-balance accelerometer with a natural frequency of 450Hz and a damping factor of 0.707 (standard values) The output is 3V/g and the resolution is more than 1 mGal.

### 2.2.2 Recording system

The recording system of the K-NET95 consists of 6 parts as shown in Figure 3. The final scale of strong-motion records stored on IC memory is adjusted by the gain of a DC amplifier,  $A(f)$ , where  $f$  is frequency in Hz. An analog filter,  $F(f)$  is an antialias filter for an A/D converter,  $C(f)$ . This filter consists of a two-stage RC-filter with the time constants of  $1/12,600$ s and  $1/62,600$ s. The A/D converter,  $C(f)$ , is a 24-bit type with a converter clock frequency of 1.6384MHz. Strictly speaking, this A/D converter consists of a 1-bit sigma-delta modulator and the following digital decimation filter. This digital filter is a linear phase finite impulse response (FIR) filter with a tap length of 1.25ms, and the oversampling ratio is 2048. Thus, the output of  $C(f)$  is a signal with a sampling frequency of 800Hz, that retains the causality of the original signal. A digital filter,  $D(f)$ , is also a decimation filter. This filter is a 3-pole Butterworth filter with a corner frequency of 30Hz, that decreases the sampling frequency from 800Hz to 100Hz. Finally, the signal with a sampling frequency of 100Hz is stored on IC memory. A flash memory card with a recording capacity of 8MB is used for the data storage The maximum available time for recordings is 2.5 hours. The maximum measurable acceleration is 2,000Gals.

Figure 4 shows the overall frequency response characteristics of the K-NET95. This response characteristics are approximately equal to those of a 3-pole Butterworth filter. Thus, the K-NET95 instrument correction may be easily done in Fourier domain. However, it may be difficult to do instrument correction in time domain, because and digital Butterworth filters with a sampling frequency of 100Hz do not keep the Butterworth characteristics in a frequency range from 30Hz to 50Hz.

### 2.2.3 Time-code

Timing in the K-NET95 is controlled by using Global Positioning System(GPS) satellite systems. A GPS antenna is installed in each site and

the K-NET95 has a GPS engine.

#### **2.2.4 Resolution and dynamic range of the K-NET95**

Figure 5 shows the acceleration power spectral density of the K-NET95 instrument noise (UD-component) obtained at the TKN site, a quiet granitic rock site. Two dotted lines, LNM and HNM, in Figure 5 show the USGS low and high noise models (Peterson, 1993), respectively. Also, Figure 5 shows the acceleration power spectral density of a UD component microtremor observed from the STS-2 seismometer at the same time. The result obtained from the STS-2 may represent true microtremor at this site, and thus the spectrum obtained by the K-NET95 probably consists almost entirely of instrument noise. Specifically, it is the resolution power spectrum of the K-NET95. This resolution spectrum shows the standard characteristics of electrical instruments.  $1/f$  noise predominates in the low frequency band and white noise controls the mid-frequency band. The spectral decay in the high frequency band is due to the decimation filter.

The peak acceleration amplitude at a frequency is calculated from the acceleration power spectral density shown in Figure 5. The results are shown in Figure 6. This figure shows that K-NET95 amplitude resolution is about 1mGal in a whole frequency band.

Figure 5 Power Spectral density

Also, the instrument noise level is from 15 mGals in RMS. This means that amplitude and has a range of 7mGals in RMS. This means that the K-NET95 has the dynamic range of 108dB because the maximum measurable acceleration of 2,000.

#### **2.3 Access to K-NET information**

The K-NET provides four kinds of data, site data, strong-motion data, maximum acceleration map, and K-NET95 instrument parameters. The control center sends these data on the Internet according to the user's request. The Internet address of control center is <http://www.k-net.bosai.go.jp/>.

## **Figure 6 K-Net 95 amplitude resolution**

### **2.3.1 Site data**

At each station, the velocity structure beneath the site to a depth of 10 or 20 m was investigated by downhole measurement. As the site data, the control center provides the location, elevation, address, and soil structure including N-values, density, P-and S waves, and soil-column for each site.

### **2.3.2 Strong-motion data**

The control center makes kinds of strong-motion data files (UNIX, DOS and ASCII) with a common header including the quick source parameters determined by JMA for each event. The user can select one of the three files on the Internet. Of course, the files of UNIX and DOS are compressed by standard compression methods.

A separate data file is made for each component of each seismogram. The numerical data in each file are raw accelerograms recovered from the K-NET95, without any corrections. The source parameters, origin time, epicenter location, focal depth and magnitude, written in a header of data file are a preliminary report on the earthquake source. The control center does not release the JMA final source parameters on the Internet. However, the control center is going to release strong-motion data off line by using CD-ROM and/or DAT after the final source data are determined by JMA. The header information regarding the earthquake source in these off line data files will be changed to the JMA final source parameters.

### **2.3.3 Maximum acceleration map**

The map of maximum acceleration with equi-acceleration contour lines will be made when the control center has recovered enough data. Then the contour lines are smoothed by using appropriate functions and indicate the center point of strong-motion, which may be different from the epicenter of the earthquake. When the control center has not recovered enough data, then the table of maximum acceleration will be released.

### **2.3.4 The K-NET95**

The control center provides the information on the K-NET95. These



are the block diagram, overall frequency characteristics and specifications of the seismograph.

### **3. Applications**

The data from the K-NET can be used for various of earthquake engineering and seismology. If the K-NET is used together with other observation networks, applications in a still detailed studies will be able to expect. This report describes the following two as fundamental examples of the K-NET application.

#### **3.1 Displacement from the K-NET95 accelerogram**

All seismographs using semiconductor circuits have  $1/f$  noise. Therefore, it is impossible to make displacement waves by integrating the K-NET95 accelerograms in low frequencies including a DC component. Figure 7 shows acceleration power spectra calculated from the accelerograms shown in Figure 8. Increase in the spectrum in a frequency range lower than 0.2Hz in Figure 7 is due to  $1/f$  noise, and integral in this frequency range does not have any physical meanings. If integral is performed by force including this low frequency components, the displacement waves obtained as a result will have severe drift components. For this reason, a method of intercepting  $1/f$  noise by using a high-pass filter is used. A reasonable method to determine the cutoff frequency of such a filter will assign a frequency point that  $1/f$  noise begins increase to the cutoff frequency. Judging from the spectrum shown in Figure 7, about 0.2Hz will be able to consider as this frequency point. Figure 9 shows the displacement waves obtained by carrying out integral operation after using a high-pass filter with a cutoff frequency of 0.2Hz. The frequency point which the increase in  $1/f$  noise begins depends on the scale of an earthquake and the distance from a observation station to the earthquake source. This frequency point will become lower as an observation site is near the same earthquake source, for example. It becomes impossible to ignore the influence of  $1/f$  noise anyhow, if the signal level of a seismogram becomes below the resolution amplitude of the K-NET95, i.e., 1mGal.

**Figure 7 Calculated acceleration power spectra**

### **3.2 Seismic intensity**

Seismic intensity defined by the JMA is calculated in the following procedure. 3-components seismogram is first filtered in a frequency domain, and then a new seismogram is synthesized in a time domain by applying inverse Fourier transform to the filtered wave. This filtered wave has a property which averaged the property of acceleration wave and that of velocity wave. The JMA seismic intensity is calculated from this synthesized 3-components seismogram. Thus, the mapping of JMA seismic intensity of an earthquake is one of fundamental application of the K-NET.

#### **Figure 8 Observed accelerograms caused by other shock of Hyogo ken-Nambu Earthquake**

#### **Figure 9 Displacement waves**

A JMA seismic-intensity distribution shown in Figure 10 was obtained to the Choshi-oki earthquake of September 11, 1996. The magnitude of this event is 6.2. The epicenter of this shock is indicated by "X" in Figure 10. In spite of distributing the K-NET station almost equally, the region where has noticed the shock of the earthquake has inclined toward the Pacific Ocean side. In other words this region is within the volcanic front of Japan and is east side. This suggests that seismic waves are greatly attenuated near the volcanic front. That is, this seismic-intensity distribution indicates that not only the influence of local site condition at a site but also the influence of the global structure under Japanese islands contribute to seismic intensity.

#### **Figure 10 Distribution of JMA seismic intensity caused by the 1996 Choshi-oki earthquake with magnitude 6.2**

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*UNCRD's Anniversary Commemorative Programme*

*10<sup>th</sup> International Research and Training Seminar on Regional Planning for Disaster Prevention,*

United Nations Centre for Regional Development, 12 December 1996, Nagoya, Japan

## **Disaster and Environment Monitoring using Remote Sensing data and GIS Technology in Mongolia**

by

**B. Bayasgalan**

### **1. Introduction**

Mongolia is a country with one of the high frequencies of natural disasters. Also the main economic branch of Mongolia is agriculture which is closely dependent on the natural condition. Natural disasters are one of the reasons of poverty and cause socioeconomic problems also seriously affect the environment. This paper presents the current state of the environment and disaster monitoring using remote sensing data and GIS technology. Mongolia is situated in the northern part of the Great Gobi desert of Central Asia and frequently experiences natural disasters such as drought, dzud and fires. In Mongolia the main economic branch is agriculture and livestock which is closely related to natural disasters. Natural disasters cause not only economic losses but also seriously affect natural resources and are one of the reasons of poverty in the countryside.

The 1/3 of the population and 1/2 of the livestock live in high frequent drought areas. According to statistics in an average year the yield losses are 14-15% of the total yield, livestock losses are 300-400,000 head and direct losses are 18.5 million US \$. The extent of areas experiencing drought has a trend to increase with every year due to variations of the global climate, biological and anthropogenic factors. Forest and grassland play an important role in the developing economy. Forest is 10% of all territory. 1/2 of the territory is dry area. In an average year occur the 50-60 forest fires and 80-100 steppe fires. They damage about 70,000 hectares of forests and 700,000 hectares of grassland. The economic losses exceed 10 billion tugrik.

In thus year were registered 368 cases of fire, 25 deaths of the people and 10,000 head of livestock's died, were burned 2363 thousands hectares of forest and 7830.9 thousands hectares of grass. Total economic losses are 2 billion US \$.

Main disaster of winter season is dsud. Severe dsud which cover more than 50 percent of territory occur once per 4-5 years. On the average every year loss 0.5-0.9 million head of livestock due to the dsud. For example, the spring of 1996 in the territory of Mongolia kill people and livestock has been observed forest and step fires. In this disaster 25 people have been killed and 65 people has injured. Also 7000 livestock killed and 210 houses has been burned.

For disaster monitoring we are using the NOAA and Landsat satellite data. We have losses is from this is 2 billion US dollar. Other natural disaster is snow storm. In April 1980 in Mongolia has occurred strong snow storm. In this storm killed 150 people and 0.6 million livestock and results in about many million US dollar worth of economic loss. In Mongolia has been developed the methodology for estimating and monitoring atmospheric storms such as heavy rain, dust storms, snow cover, drought conditions using remote sensing and ground data.

The quality of environment has been badly effected particularly due to release of pollutants into the aquatic and atmospheric environment domestic and industrial wastewater discharges have caused significant contamination of surface waters. The main sources of air pollution are coal-fired cooking and heating stoves, coal fired heating and power plants, industries and vehicles. Such kind local pollution estimated using remote sensing data and GIS technology. On the basis of the processing and analyzing NOAA satellite data delivered the daily temperature dynamics of various terrain surface, monthly changes of the vegetation and snow cover for whole territory, forest and step fires on big areas. Also we are widely using the remote sensing and GIS data for desertification and

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drought monitoring. Desertification is a country wide phenomenon affecting all territory of the country and gradually decreasing natural resources of land. It estimated that all people who is living in Gobi area are directly treated by desertification. The immediate cause of desertification in the territory of Mongolia are well known viz, overgrazing, the felling of trees for fuel, water logging, salination and bad agricultural practices. In Mongolia has been developed method for estimating the drought severity using the satellite and ground.

Land resources degradation is good research subject for remote sensing and GIS Technology. Land resources are and will continue to be of critical importance to Mongolia, where extensive, pastoral agriculture and related agricultural product industries account for a significant portion of the national economy and domestic food supply, and a growing component of the economy and domestic food supply is based on rapidly expanding cultivated crop agriculture. Low natural vegetative density and productivity, even in undisturbed areas (due to the harsh climate) mean that greater areas of non degraded land are required per unit product tion than is the case in other countries or regions. Available data indicate a that the area of formerly productive land in which has been degraded (rendered less productive or nonproductive) has increased significantly in the past two decades. Mongolia has more than ten environment protected areas. Remote sensing and GIS technology are using for mapping of protected areas which to used for protected areas management. Other environmental areas for application of remote sensing and GIS technology is water resources of Mongolia. Remote sensing data and GIS is useful tool for river basis management in Mongolia.

Last area for application of the remote sensing GIS technology is dust storm. Remote sensing studies of dust storm showed that dust storms occurred in southern part of Mongolia 20-30 days each years. In particularly bad years these storms can last up to 350 hours. During the past 30 years the number of dust storms in the Gobi area has increased 2 times.

One of the biggest dust storm occurred in Gobl area in November of 1992. Wind speed during this storm reached 40 m/sec, flattening over 500

local houses, hundreds of animal shelters. The border areas of the above dust storm has been determined by satellite data. Also dust storms cause air pollution in east Asian countries in the spring. For example, dust clouds stirred up in storms over the Gobi area polluted ground and surface water in Japan. This scientific problem has been investigated using satellite data.

TTrue and operative information on natural disasters is required for natural disaster management. Convenient ground field information are not benefit in time, cost and space.

The results of this study show remote sensing and GIS technology can provide wide area, operative and cost effective information on natural disasters such as fire, drought and dzud. It is very useful for Mongolia, which has vast territory, weak economic capacity and sparse population.

## **2. Environmental emergencies in Mongolia**

The purpose of this chapter is to review the scope and nature of potential environmental emergencies in Mongolia. The chapter begins with a brief review of the geographical and socio-economic context of contemporary Mongolia, and then discusses the various kinds of natural disasters and industrial risks that can occur.

This chapter includes a summary of the statistical aspects of disaster risks in Mongolia. However, it should be noted that treatment of disasters in terms of raw, national statistics does not give a full picture. In practice, many of the consequences of a given disaster are quite localized or confined to a region at most. Moreover, the capacity of one part of the country to come to the aid of another part is often limited by difficulties of transport and communication, especially during the periods when it is most needed.

### **2.1 Geographical and socio-economic context**

Mongolia is situated in Central Asia. It is 1,600 km from the Pacific Ocean, 3,000 km from the Arctic Ocean, and 5,000 km from the Mediterranean Sea. Mongolia experiences a continental climate, with hot summers (temperatures up to 41 degrees Celsius) and cold winters (temperatures down to -50 degrees Celsius) Diurnal temperature changes

can also be very large at certain times of the year. Rainfall is relatively low, varying from 5 cm in southern, desert regions to 40 cm in mountain areas. Some 80-96% of the precipitation falls during the warm period from April to October. In the south, significant rainfall does not begin until July.

About 40% of the country is mountainous (more than 1,500 m above sea level), another 40% is hilly (from 1,000-1,500 m above sea level) and the remainder is denuded plain. The geography includes alpine, mountain taiga, forest step, steppe, Gobi, and desert regions. Rivers draining to the south and west terminate in inland lakes or salt marshes (*Mongolian National Atlas 1992; Atlas of Resources 1986; HRI Papers*).

The growing season is short, ranging from 70 to 130 days depending on latitude and altitude. Unseasonal frosts can destroy up to 30% of crops. Crops are mainly root crops, wheat, garden vegetables (including some greenhouse vegetables grown near Ulaanbaatar), and hay fodder. The main agricultural production is animal, with herds of cattle, sheep, horses, camels, and goats.

Wind speeds are often high, with dust and sand storms for an average of 40 days per year over a large part of the country, and for an average of over 100 days per year in some regions.

The population of Mongolia was estimated at 2.3 million in 1992, with about 27% of the total population living in the capital (Ulaanbaatar). The most densely populated rural areas are the river valleys in the forest-steppe zones. The least populated areas are the semi-desert, desert, and mountain-taiga zones. The rural population is about 43% of the total, and the urban population is about 57% (*Mongolian National Atlas 1992*; Approximately 800,000 people live in large settlements, including 500,000 in Ulaanbaatar, 88,000 in Darhan, and 57,000 in Erdenet. Of this population, 26% are aged less than 10, and 3% are 70 years or older (*Mongolian Yearbook 1996*).

Average per-capita income is only just over 100 US \$ per year. Although there is undoubtedly a significant non-monetary economy in

Mongolia (e.g., the growing of vegetables or the raising of animals for personal consumption or perhaps barter), there are still 510,000 people, or 23% of the total population, who are recorded as living below the official poverty line.

Agriculture is a dominant part of the economy and livestock production is the biggest part of agriculture. The total number of livestock is estimated at 25 million, mostly sheep and goats but with horses, cattle, and camels amounting to 22% of the total. Livestock density is estimated to be close to the carrying capacity of available pasture lands; and, in some of the poorer seasons, it probably exceeds the carrying capacity. Annual livestock losses since 1986 have varied between 0.5 and 1.0 million head, with the average loss being around 800,000 head. These losses represent about 5% of the total national herd and about 6-10% of the Gross National Product (GNP). Over the years, natural disasters have accounted for at least half and sometimes nearly all (93%) of these losses. Note, too, that losses are often concentrated in a particular region of the country and that the losses may be catastrophic at that level, even if they represent only a small percentage loss at the national level: *Mongolian National Atlas 1992*.

Large areas of the country operate on the basis of a non-cash (barter) economy, with goods being exchanged directly for livestock, skins, wool, or handmade products. The lack of a cash economy can create problems for several types of emergency measures; for example, the purchase of emergency fodder-supplies may be difficult or individuals may find it difficult to pay for crop or livestock insurance. In areas where crop growth is lowest, agriculture is semi-nomadic, with herds being moved frequently to reduce the burden on pasture-land.

Mongolia has limited transportation infrastructure. There is a single, main-line railway that crosses the country from Russia in the north to China in the south. It has 1,800 km of main line and an additional 200 km of feeder lines and side-tracks. There are 42,000 km of main roads but only 300 km are paved. The population density is generally low (outside Ulaanbaatar), so that an extensive road network would be hard to justify, and expensive to maintain. The result is that most long-distance transport



in Mongolia is by air. This has a significant effect on emergency preparedness, especially in the winter and spring, when unpaved roads become very slow and difficult.

The telephone system in Mongolia covers most of the country, with an average of about 4 lines per 100 persons. The density is naturally greatest in Ulaanbaatar (6 lines per 100 persons) and quite low in remote areas. Most of the cross-country lines are made of copper wire strung on wooden telephone poles (making the lines vulnerable to fire). There are sixteen radio transmitters operating in the VHF, short-wave, medium-wave, and long-wave bands. In very remote areas, private telephones are effectively precluded by distance and the lack of any electricity supply.

The dependable electrical-supply throughout the country amounts to about 800 mW. The Central Electricity System (CES) consists of coal-fired thermal plants, has a total capacity of 690 mW, and is connected to the Russian electricity grid by a 220 kV line. The CES provides service to cities and towns containing about 500% of the total population and covering about 30% of the territory of Mongolia. Outside the CES grid, power is produced by means of a 36 mW coal-fired plant at Dornod and by means of numerous diesel-electric generators. Outside the cities, towns, and villages, many farms and most nomadic settlements are completely without central electricity. A few settlements make use of small wind-generators.

In short, emergency preparedness in Mongolia takes place in the face of at least three significant constraints: poor transportation infrastructure, poor communications, and lack of electricity. Generally speaking, these problems may affect anywhere up to half the entire population.

## **2.2 Natural disasters**

Natural disasters take a variety of forms in Mongolia. Among them are: blizzards, zud, flooding, dust storms, droughts, earthquakes, and wild fires. In the following sections, we review the nature and impact of each of these types of natural disaster. We shall deal in more detail with emergency responses to each type of disaster in chapter 5 below.

### **2.2.1 Blizzards**

Blizzards generally occur between September and May. Their duration may be quite short (Just a few hours) or up to ten days. The number of blizzard days can vary from less than two in the steppe areas in the west of the country, to up to eight in the eastern part of the country. In some mountainous areas, blizzards can last for up to ten days at a time. Blizzards can be extremely dangerous with heavy snow and winds of up to 35 m per second (126 km per hour). Moreover, heavy snowfall can have serious consequences for agriculture, if they prevent livestock from reaching suitable pasture. In fact, it is hard to distinguish the effects of the blizzard (chilling) and those of heavy snow (exhaustion and starvation) on livestock. Table 1 below shows the effects of some recent blizzard disasters in Mongolia.

**Table 1 Selected consequences of recent blizzard disasters in Mongolia, 1986-96**

### **2.2.2 Zud**

A Zud is a Mongolian word for a disaster in which livestock are prevented by snow, wind, or cold from reaching grazing pasture for long periods of time. If a zud occurs in combination with another type of disaster, the damage can be catastrophic. The occurrence of a zud appears to depend on the intensity, duration, and repetition of snowfalls. However, efforts to reduce the zud hazard have so far been largely unsuccessful.

For centuries, Zud have caused extensive property damage, and affected social and economic conditions throughout the country. According to historical records, there were 15 occurrences of zud in the 18th century, 31 in the 19th century, and (so far) 41 in the present century. In other words, the current, annual probability of a zud is nearly 40%, or one occurrence every 2.5 years.

Zud are typically the worst kind of natural disasters in terms of the number of livestock lost. In 1944-45, for example, 8 million head, nearly a third of the national herd, were lost; and in 1967-68, 2 million head, about 80% of the total herd were lost.

### **2.2.3 Flooding**

Floods can occur in several ways in Mongolia. Heavy summer rain can cause floods in rivers emptying into the Gobi. Heavy rains can also cause floods in the north and east of the country. Snow melt can cause spring floods in rivers in the west, east and north. In mountainous areas, snow-melt floods occur almost every spring. In general, floods can affect human settlements but most of the damage they cause is to soil quality and fertility, crop land, railways, bridges, and roads. Fatalities are avoided for the most part, because floods are normally anticipated.

The frequency of floods due to heavy rain is estimated at 1 every 6 years and of floods due to snow melt at 1 every 4.5 years. Generally speaking, losses of USD 5-6 million are typical from flooding due to rain, USD 0.7-1.1 million from flooding due to snow melt, and USD 1-2 million from flooding due to dibaish flow. Floods in 1991-93 killed a total of 62 people (HRI Papers).

A special phenomenon is the dibaish flood, which results when heavy rain falls on snow and ice, resulting in a flow of ice and debris. Dibaish flow typically occurs at the end of the summer in mountains without forest cover. It can sometimes leave people and livestock dead, as well as significant property damage. For example, a dibaish flood occurred in Ulaanbaatar in August 1992, resulting in the death of more than 20 people and causing \$500,000 in property damage. Details of other major floods in Ulaanbaatar in the last twenty years are given in Table 2 below.

**Table 2 Selected consequences of recent flood disasters in Ulaanbaatar, 1986-96**

### **2.2.4 Dust storms**

Most of the country is affected by dust storms for at least 40 days per year, and some areas are affected as much as 100 days per year. When storms last more than 10 days in succession, the effect on livestock becomes serious. Wind speed of more than 40 m per second, or 144 km per hour, can occur.

### **2.2.5 Droughts**

Mongolia is situated in an area of the Asian continent with relatively low rainfall and is one of the most drought-prone areas of the world. Moreover, the frequency of droughts appears to be increasing, as the drought index has more than doubled over the last 50 years. In the arid zone to the south, the frequency of drought is now estimated at one every 2-3 years. In the steppe zone, it varies from one every 4.5 years to one every 5.3 years.

Moreover, drought affecting more than half the entire country has occurred 12 times in the last 50 years. On average, droughts of this severity have killed 350,000 livestock and reduced crop growth by half. In addition, droughts can cause significant, if unquantifiable, reductions in herd fertility.

### **2.2.6 Earthquakes**

Mongolia has several active earthquake zones. In this century, there have been eleven earthquakes that recorded an intensity of more than 6.8 on the Richter scale and four that recorded more than 8.0.

About a third of the major cities and towns in Mongolia are located in active earthquake areas; overall, about 80% of the country is in an earthquake-prone zone. Traditional Mongolian housing (the ger or yurt) is highly resistant to the effects of earthquakes. Wooden and wood-frame housing with clay walls is less resistant, and fire resulting from earthquakes is always a risk. However, the major damage due to earthquakes is caused to industry and transportation infrastructure. (*Mongolian National Atlas 1992*).

The largest earthquake in this century was in 1957. Twenty people and several thousand animals were killed, and property damage amounted to about USD 25 million (*Earthquake Report, 1960*). The relatively low population-density in Mongolia means that losses from individual earthquakes are generally limited, but there is a potential for major catastrophe, if an earthquake were to affect one of Mongolia's major cities.

### **2.2.7 Wild fires**

Forest and grassland fires occur in Mongolia every year. Over the last 15 years, a total of 1,065 forest fires have burned 3 million ha of land, including 20% of the total national forest area. Over 200,000 ha are estimated to have been permanently lost to forest growth. Roughly twenty times as much timber is lost to forest fires as is harvested.

As for grassland fires, about 100 large fires occur every year destroying from 700-800,000 ha of grazing land. In the first half of 1993, 470 grassland fires killed 33 people, burned 31 houses, and destroyed 85% of pasture land in three sum in Suhbaatar aimag. Major grassland fires occurred in the first half of 1996, with preliminary reports of 200,000 ha burning in a single fire.

### **Forest and steppe fire in Mongolia, 1996**

#### **Number of fires and area burned in Mongolia during spring 1996**

Source: State Emergency Commission

#### **Map of number days with snow storms in Mongolia**

**Map of storm wind speeds from November, 1992 obtained using satellite and ground data**

# FIRE in 1996

- Fire exceed 6 times average (386 cases)

## DAMAGE

- 25 people died & 65 seriously injured
- 7000 livestocks, 210 house, 1120 other facilities
- 2.3 million hectares of forest  
(total 17.5 mill. hec)
- 7.8 million hectares of grassland

Losses= 2 billion US \$

*UNCRD's Anniversary Commemorative Programme*

*10<sup>th</sup> International Research and Training Seminar on Regional Planning for Disaster Prevention,*

United Nations Centre for Regional Development, 12 December 1996, Nagoya, Japan

## **An Alternative Methodology for Seismic Risk Analysis and Assessment in Large Urban Centers**

by

**Carlos Montoya-Dulche**

### **Abstract**

Over the last years, seismic risk analysis methodology has been formalized in several ways. In this paper a new approach based on Object-Oriented Programming (**OO**P) will be discussed. Commonly, **OO**P is applied for computer system development; however, in this case it is the theoretical framework too. In this context, any item subjected to a seismic-risk, in terms of its vulnerability and its location in a seismic hazard domain, can be totally defined by a Seismic Risk Object (**SRO**). Each **SRO** consist of the *inheritance* of several *classes* that represents all the intrinsic characteristics of the entity under analysis. These classes are the *topology*, which defines the geometry and location of the entity in a hazard domain, the *vulnerability*, that contains several functions which provides the risk level in terms of the exposed hazard and the information class whereby the analysis of the risk can be done.

The theoretical model can apply an additive operator among **SRO** to generate a new object composed by higher-recursive objects in such a way that the result of the application of any algorithm under a higher-recursive object is equivalent or even exact if the integration at the independent results for each component object is done. This is the most important feature of the **SRO** approach because increase dramatically the speed of risk assessment and permits to establish different recursive level for the same risk assessment model to be applied in early estimation systems.

The **SRO** theory was formulated in most general terms such that different hazard

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estimation, vulnerability, evaluation, and risk analysis models could be defined satisfying the necessities of a particular problem. Even more, the same concepts can be effectively applied to an other risk evaluation context by simply changing the meaning of functions involved.

Using this approach a complete computer system has been developed and currently a prototype is available. The **SRO** System provides all the computational support to build very complex models to estimate and analyze the seismic risk in large urban centers. It applies, besides sophisticated algorithms to handle **SRO**, a powerful graphic interface with some features of GIS techniques.

## 1. What is OOP ?

Basically, Object-Oriented-Programming philosophy assumes that any entity (*object*) contains in itself all the variables and procedures (*methods*) associated to its intrinsic nature. In this scheme, an object is defined by two issues: *state* and *behavior*. The *state* is a group of data types that defines certain internal parameters of the object. The *behavior* is a set of functions or methods whereby the object responds to an specific *message* in which the state could change. State and behavior are grouped or *encapsulated* to define a *class*. *Class* are the base of **OOP**. A class provide the information for a data type, so when an object is required an *instance* of the class must be done. Obviously, these data types can be directly included in a new class definition as an other variable of the object's state; however, the **OOP** provides the *inheritance* mechanism whereby a new class will take the state and behavior of the parent class plus its own issues. Furthermore, a new class could have more than one parent class.. When a class is defined, its complete arithmetic can be stipulated. In this way any operator can attend directly to the characteristics of the class.

## 2. Initial premise

The fundamental premise in which **SRO** theory is formulated is the follow:

*“Any item subjected to a seismic risk, in terms of its vulnerability and its location in a seismic hazard domain can be totally defined by a Seismic Risk Object”*

The meaning of the terms applied in this phrase must be defined.



**Hazard** is any disturbing phenomenon of the environment of an object, generally the soil movement, even though can be any other parameter. **Hazard domain** is the spatial extension in which the hazard is defined. The vulnerability, which depends of the object, is a group of functions that represents the susceptibility of an object to present some kind of damage. Finally the risk, which is the product of combining hazard and vulnerability, and represents the damage or prejudice of an object measured in terms of some quantitative unit.

### 3. General conception of SRO theory

The basic idea of the **SRO** theory is the recursive composition of objects composed by objects; i.e., basic or **atomic** objects are added or grouped in bigger objects. The main point of this approximation is that all objects, without importing their composition, will be analyzed and processed using the same methods.

Imagine an object  $O_i$  that upon receiving the message “**What is the risk level?**” responds  $R_i$ . Under this premise, the total risk can be computed as:

However, this process involves n messages “**What is the risk level?**” Spending a lot of computer time. Following the basic idea of **SRO** theory, it is possible to add **a priori**  $i$  the n objects in a single one  $O_t$  as follows:

in such a way that  $O_t$  will respond, in a single message **What is the risk level?** directly  $R_t$ . On the **SRO** context, each group of objects composed by objects is called **recursive level**. The **minimum recursive level** is when an object does not belong to another object, this means, the object is the result of a final aggregation. This kind of object is called **Root object**. On the other hand, when an object is the base of an aggregation i.e. the object it is not composed by other, the maximum **recursive level** is present These objects are called **Atomic objects**.

### 4. Hazard domain

For **SRO** theory the hazard domain assessment assumes that exists a point, real or hypothetical called *Basic Hazard Center (BHC)*, where the hazard can be computed and it can be transferred by means of a function to any place inside the hazard domain. The hazard computed, using some known procedure, in the **BHC** is called *basic hazard  $H_{o_0}$* .

Based on the above, the basic hazard is defined by:

$$H_{o_0} = H_{o_0}(H_a)$$

where

$H_{o_0}$  is the basic hazard or *basic hazard ordinate* and,  
 $H_a$  is the *hazard abscissa*.

The meaning of this function will depend on model that the user wants apply. For instance,  $H_{o_0}$  could be the spectral acceleration and  $H_a$  the structural period.

Once  $H_{o_0}$  has been defined, it is possible to compute the hazard  $H_o$  in any place inside of the spatial domain (hazard domain). In the latter it is assume that a transfer function  $FT$  is known. In this way,  $H_o$  is calculated as follows:

$$H_o(x,y,H_a)=H_{o_0}(H_a)FT(x,y, H_a)$$

where

$H_o$  is the transferred hazard and,  
 $x,y$  are the spatial coordinates.

It is clear that the hazard domain itself is independent of the basic hazard because the latter does not depends on its location, however, a linear behavior is accepted. Generally, this hypothesis is enough for the majority of the problems. If non-linear behavior is to be simulated, it is possible to define a set of different transfer functions.

The determination  $FT$  could be a very difficult task. However, the **SRO** system offers powerful tools. [1]

## 5. Composition of SRO

A SRO in the inherence of tree classes: *Topology*, *Vulnerability* and *Information*.

### 5.1. Topology

The topology is the geometric representation of an object located geographically. Its structure is based on several graphic items like lines, polygons, points and, inclusive, text.

The topology is used for two reasons in the **SRO** context. The first one is to represent maps overlapped in several layers of graphical information and the second one is to link an object to the hazard domain. This link performed using the *Seismic Hazard Center* SHC. SHC is the average of the coordinates of the graphic items that constitute the atomic object. When an aggregation is done, the new object presents a new **SHC** that corresponds to the average of the **SHC** of each **SRO** involved.

### 5.2 Vulnerability

In **SRO** theor)', it is accepted that the risk **R** it is represented by the product between the *exposed value* **U** and the *risk index* as follows:

$$R=U I_R$$

The exposed value is a scalar that represents the total of a quantitative unit subjected to risk. For instance, \$, inhabitants, m<sup>2</sup> etc. The risk index is a function of the hazard that represents the percentage of exposed value that will present a specific risk. The formed mathematical definition of the risk is:

$$I_R = I_R(H_o)$$

However, **H<sub>o</sub>** is a function of spatial parameters and an specific hazard abscissa (**Ha**), so that:

$$I_R = I_R(Ha;x,y)$$

This condition is very useful in the **SRO** formulation since *Ha* is an intrinsic characteristic of the object. For instance, a building which its damage is a function of the spectral acceleration (*Ho*) and the acceleration function of the spectral period *T(Ha)*.

Based on the above, a *vulnerability function* used in the **SRO** theory is given by, the exposed value **U**, a hazard abscissa *Ha* and, the risk index *I<sub>R</sub>*.

To increase the **SRO** vulnerability formulation, it is necessary to bear in mind that an object could needs more that one hazard abscissa thus, the concept of risk item is included. Risk item is a group of several vulnerability functions with different *Ha* under a generic name. For instance, buildings between 5 and 10 stories. Under this condition it is clear that different periods associated to each height is required. Even more complicated it is possible to think in a vulnerability model in which a damage is evaluated taking higher modes of vibration.

Whichever is the type of approach used, there will be several elements that represent the expected risk in terms of different exposed values. To include this condition a risk block is defined as a group of several risk items with same exposed value. For Instance:

Risk block:	<i>"Expected damage"</i>
Exposed value	<i>m<sup>2</sup></i>
Risk items:	<i>Housing</i>
	<i>Buildings</i>

### *Monuments*

Finally, an object could simultaneously present several types of risk in terms of different exposed values. So, the vulnerability of a **SRO** is defined by:

*The vulnerability of an object is a set of risk blocks that defines the sensibility of an object to a specific hazard.*

### 5.3. Information

With the topology and vulnerability of an object it is possible to evaluate the expected risk level ( *risk assessment* ). However, what would happen when a certain risk level exists in an object? This question is the risk analysis and the answer is performed with the *information*.

A **SRO** will have associated a set of individual elements ( **Information base** ) which defines the complete information. These informative items have the following structure:

<b>Field</b>	defines the name of the informative element,
<b>Type</b>	establishes the data type and,
<b>Data</b>	give the value of the informative element.

The data types are classified as descriptive, quantitative and codified. The descriptive data type, is a character string with irrelevant information for risk assessment, but useful when a model is been developed, e.g. *address, date*, etc. Quantitative data types are numbers, real or integers, that represent the amount of a certain characteristic, e.g. *area, number of physicians*, etc. The codified type is a string character that represents in terms of a general code to all the objects of the model, an attribute, e.g. *use constructive quality*, etc.

## 6. Risk assessment in the SRO context

It has been conceptually defined the classes that defines a **SRO**. Now the process or method before the message "*What is the risk level?*" will be described. It is known that the vulnerability of a **SRO** is given by a set of risk blocks. Therefore, the first step is to determine which is the risk block, e.g. "**Expected damage (\$)**". Following the vulnerability **SRO** structure, it is necessary to establish which is, or are the risk items for which the risk level is needed, e.g. "**Masonry with 3 stories**" and "*Buildings between 5 and 10 stories*". At this moment the **SRO** knows that a set of valid risk items  $i$  is required. Next, the vulnerability class take all the  $Ha_{ij}$  values, e.g. structural periods, associated to each  $j$  vulnerability function. With these values, the hazard is computed as follows:

$$Ho_{ij} = Ho(Ha_{ij})$$

However, it is necessary to know where the object is located. In the latter the topology (**SHC**) is used. Using the spatial location (coordinates), the hazard can be computed as:

$$Ho_{ij} = Ho_o(Ha_{ij})FT(x,y, Ha_{ij})$$

Finally, once the hazard is computed, the object will respond to the message *What is the risk level?* as follows:

This procedure may seem incomplete considering that the risk assessment is a stochastic process. However, the uncertainty can be considered by taking different hazard domains, that is, defining different risk blocks.

## 7. Aggregation of SRO

All **SRO** must change its state or behavior before messages. Perhaps the most important is *what is the risk level?*, however, there are many other messages that must be included in several processes giving the same coherence of results if an object has a certain recursive level. It may seem that **SRO** aggregation is linear; but thinking in topology and information, is it possible to talk about linearity? The answer is no. Just equivalence. In the following paragraph this point will be discussed, clarifying how the equivalence does not violate the **SRO** approach.

### 7.1 . Adding topology

The topology aggregation is easy. Think about a draw composed by draws. Maybe the most complicated issue in this process is how the new **SHC** is computed. When a **SRO** is atomic, the **SHC** is the average of all coordinates that compound the graphic item involved. If the **SRO** is root or it has some recursive level but not the maximum, the **SHC** is computed by the average of all the **SHC** of each **SRO** considered.

### 7.2. Adding vulnerability

The coherence among different recursive levels is always possible but involved several special considerations.

When the **SHC** changes? In two circumstances. The first one is due to the topology aggregation. The second one is when a topology an object it is directly changed. The last circumstance may seem with to sense; however, sometimes it is useful to change the topology of an object. For instance, it is possible to have several building lots aggregated in an object called block as many polygons, one for each building lot, or a single one, directly the block. The effect of the **SHC** change over vulnerability is logic thinking that the aggregation will provide an equivalent **SRO**. This means different topology, different vulnerability but equal risk. Whatever is the reason for change, the vulnerability must represent the new susceptibility of the object. The change of the vulnerability can be explained by means of changing the procedure of a vulnerability function.

A vulnerability function is made of:

$U$	Exposed value
$Ha$	Hazard abscissa
$I_R = I_R(Ha; x_1, y_1)$	Risk index

where  $x_1, y_1$  are the coordinates of the initial **SHC**.

Obviously, the value of the hazard abscissa and the exposed value do not change because equivalent **SRO** being analyzed. Thus, the coherence due to the **SHC** alteration is supported by the risk index. Assume that  $Ho_1$  and  $Ho_2$  are the hazard of the original and modified **SHC** coordinates respectively, the following is accepted:

$$Ho_1 = Ho_0 FT(Ha; x_1, y_1)$$

$$Ho_2 = Ho_0 FT(Ha; x_2, y_2)$$

where  $(x_2, y_2)$  is the new **SHC**. To clarify the discussion, a change of variables is done. This means  $FT(Ha, x_i, y_j) = CT_i$ , so  $Ho_1$  and  $Ho_2$  will be:

$$Ho_1 = Ho_0 CT_1$$

$$H_{O_2} = H_{O_0}CT_2$$

and the risk index:

$$I_R = I_R (H_{O_0} CT)$$

Based on the above the new risk index in  $(x_2, y_2)$  can be expressed as:

$$I_R = I_R [H_{O_0} (CT_1/ CT_2)]$$

When two vulnerabilities are added, several problems have to be solved: the change of **SHC**, the coherence between two exposed values and, generally, several hazard abscissas. Showing each possible combination of the circumstances could be useless. However, by discussing the change of **SCH** and the aggregation of two vulnerability function, all the other solutions can be elated.

Let's assume two vulnerability functions with the following parameters:

**Function 1**

$U_1$	Exposed value
$Ha_1 = Ha$	Hazard abscissa
$I^I_R = I^I_R (Ha; x_1, y_1)$	Risk index

**Function 2**

$U_2$	Exposed value
$Ha_2 = Ha$	Hazard abscissa
$I^{II}_R = I^{II}_R (Ha; x_2, y_2)$	Risk index

These functions will be added in a new vulnerability function which evidently must be of the same structure:

**Total function**

$U_T$	Exposed value
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$Ha_T$	Hazard abscissa
$I^T_R = I^T_R (Ha; x_n, y_n)$	Total risk index

where  $x_n, y_n$  are the coordinates of the new **SHC**. The goal is to maintain the coherence stipulated by

$$R_T = R_1 + R_2$$

where  $R_T$  Is the risk cateehred by the Total function and  $R_1, R_2$  are the risk computed by the Functions 1 and 2, respectively.

Due to the exposed value definition, it is logic to fix  $U_T$  like the arithmetic sum of the exposed values  $U_1$  and  $U_2$ . In the same way, it is logic to consider  $Ha_T = Ha$ . Based on the above, the total risk index will be expressed as:

$$I^T_R = I^T_R (Ha; x_n, y_n) = \frac{U_1 I^I_R (Ha; x_1, y_1) + U_2 I^I_R (Ha; x_2, y_2)}{U_1 + U_2}$$

### 7.3. Adding information

Adding information is the process that best represents the equivalence. It has been discussed that each object contain its information in a set of items called Information base, which are structured in three issues Field. Type and Data, The aggregation of information can be done in presence of two circumstances. The first one is when all fields are different. In this case, information aggregated will be the easy concatenation of the information bases. When several fields are equal, aggregation process can be a little bit more complicated. Not always is possible to aggregate all data types. Descriptive fields are impossible to add. However, by definition, the information contained in these fields dose not provide any relevant information. When the data are quantitative the aggregation can be performed directly by the sum of their values.

When equal fields are codified, the aggregation process will generate two new field of quantitative type in the result information base using the field name as values contained in the field and the unit as data. For

instance, Let's assume that two **SRO** have the following information base:

**SRO 1**

Field	USE
Type	Codified
Data	U24

**SRO 2**

Field	USE
Type	Codified

Based on the above, the information base will be:

**SRO Result**

Field	U24
Type	Quantitative
Data	1

Field	U73
Type	Quantitative
Data	1

The new information base provides all the original information but in equivalent way. The meaning of the equivalent information is *"Of the use U24 the object has one element"* preserving the coherence between recursive. Obviously, if the second **SRO** would have already defined the field U24, the result of the aggregation would be *"Of the use U24 the object has two elements"*.

## 8. The SRO model

All ideas expressed herein were applied in a comprehensive computer system [2,3] called **SRO** System. For determining 3 model to estimate the seismic risk in a large urban center, the following information and methodology will be required.

- **Basic Hazard Estimation Model (BHEM)**

This model is the procedure to estimate the basic hazard, i.e. the hazard that will be transferred to the hazard domain. This model will depend on the lector. If **SRO** System is used, a computer program to estimate **BHEM** must be provided and its output will have an special format.

- **Hazard Domain Estimation Model**

This is a set of transfer function between the BHC and the hazard domain. Within the **SRO** System, several utilities to define a mesh of functions are available.

- **Vulnerability Model**

Corresponds to the function that will command the behavior of the risk index. This function must be compatible with the hazard domain, i.e. the hazard must be the abscissas of the function.

- **Atomic SRO**

It is a set of **SRO** where the topology, vulnerability and information has been initially encapsulated, i.e. the object at the maximum recursive level.

- **Recursive Composition Model**

This is the rule of aggregation, i.e. the number and identification of the recursive levels. For example, *Level 0, City Level 1, Country, Level n, Building lot.*

## 9. Final comments

The **SRO** theory permits to estimate easily and rapidly the seismic risk in large urban centers The fundamental idea of aggregation provides a good opportunity for the easily estimation systems due to the condensation of thousands of messages *"What is the risk level ?"* in single one. In the same way, this technique can be applied in urban planning and policies for emergency management.

In the last five years, all the computational support has been

developed. Currently there is a Beta version available. The **SRO** software works under SUN workstation with Solaris 2.5 operating system. Emergency management capabilities are particularly interesting because applying the International Network INTERNET, remote application can be executed in powerful servers which could send the results quickly, to local government or even to rescue teams. At present, these ideas have been ported to new applications based on **JAVA** technology and in the future this will provide an excellent support.

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*UNCRD's Anniversary Commemorative Programme*

*10<sup>th</sup> International Research and Training Seminar on Regional Planning for Disaster Prevention,*

United Nations Centre for Regional Development, 12 December 1996, Nagoya, Japan

**Development of Disaster Management Spatial Information System  
(DiMSIS) - Proposal of disaster prevention system operable from initial  
stage of disaster -**

by

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and Tokihiro Taniguchi\*\*\***

**Abstract**

An examination was made on the characteristics of disaster information by organizing the data of the disaster of the Hanshin-Awaji Earthquake with the use of the Geographic Information System (GIS). It was revealed that disaster information need to be controlled as special positional information because, in the confusion of the disaster-stricken area, It was difficult to ensure addresses. It was also revealed that continuity is important between the system used at normal times and that of emergency, and that, in order to put it into practice, time management of data is effective. A regional geographic database can always maintain the latest data through the renewals incorporated in the normal duties and can immediately respond in case of emergency. It also saves expenses greatly by dispensing with costly periodic renewals.

**1. Introduction**

The Hanshin-Awaji Earthquake victimized more than 6,300 people as well as causing damage to a large number of buildings. There was also great confusion in gathering transmitting and organizing the information of the disaster. From the experiences of the disaster this time, a need was pointed out to efficiently deal with a huge amount of disaster data so as to be promptly prepared in the initial stage in ease of a tremendous urban catastrophe. Great expectations are therefore placed on the GIS which, as a possibility, is capable of coping with this need. After nearly two years since

the great earthquake, local governments are examining the introduction of a disaster prevention system on the basis of the GIS.

This paper examines the system that is capable of responding to the actual requirements such as inquiries after person's safety, classification of damaged state, and utilization of stored data for disaster prevention. At first, an experiment was made to expand the DiMSIS, which has been developed to support the classification of disaster data and the application for the removal of collapsed houses, so that it may be applied to the task of a local government both at normal times and in emergency. Actually, the system was used in a disaster prevention drill and proved to be effective and practical. On the basis of the experience in Nagata Ward, Kobe City, this paper presents the ideal way of an administrative database and a system as it ought to be prepared at normal times.

## **2. Characteristic of disaster information and need of computerization**

In the disaster this time, the gathering of information was relied mainly on paper and pencil. Evacuees wrote their names in a book; and memos were used in the survey of stricken facilities. As a means of communication to the victims, posted bills and bulletins played an active part. Inevitably, the sorting and processing of information was done through transcript from paper to paper. It was far from the processing utilizing latest computers and communication means, making little difference from the situation in the Great Kanto Earthquake of 1923.

The necessity of computerization depends on the density of population and the extent of damage in the disaster-stricken area. In a densely populated giant city, disaster information is complicated and numerous with the readjustment hardly dependable on people's memory and paper. Especially, the number of urgent cases inquiring after persons' safety will be enormous,

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which also spread spatially in a wide area. Extracting the missing will require computing in a short time the safety information of residents evacuated in plural shelters. After that, with the removal of dangerous objects, collapsed houses, etc, grasping of daily situation will be indispensable. Issuing various certificates will also require the processing of information in a large number of cases.

A disaster prevention system is often regarded as a system exclusively used for that purpose. However, it can not be expected that a system unused at normal times is comfortably used in case of emergency. Moreover, there is no guarantee that a special disaster prevention system is free from breaking down or accessible when needed. Therefore, it is required that the computers used at normal times are also used as they are in emergency as well. Such computers are desirably those personal computers that can be commonly operated by a great number of people.

### **3. GIS for disaster management as it should be**

In applying the GIS to disaster management, contents for processing may change as time elapses after a disaster. The information system to control regional information can be classified into the following five phases based on the purpose in the lapse of time after the disaster. The flow is shown in **Figure 1**.

#### 1) Confusion stage (a few days immediately after disaster):

Inquiry after safety, rescue support, allocation of shelter, etc., are required. The disaster information is transmitted outside the stricken area through a narrow communication network.

#### 2) Initial stage (several weeks after the confusion stage):

Classification of damaged condition in houses, roads and life lines, and removal of dangerous objects are required.

#### 3) First half period of restoration (several months after the initial stage):

Classification of damage information, support for forming restoration plans, etc., are required.

#### 4) Latter half period of restoration (several years after the first half period):

Disaster analyses and support for drafting redevelopment plans are required.

5) Normal times (after completion of restoration):

**Figure 1 Flow of recovering process after disaster and role of GIS.**

Support in grasping movement of residents, supervision over fixed properties such as houses and lands, maintenance of roads and public facilities, etc., are required. By analyzing the regional situation, city planning is made for constructing a safe town with the basic data stored for disaster prevention. If information management by addresses and names is performed at normal times of the phase 5, the GIS with special specifications will be needed in the Phase 1 and 2, namely, GIS for disaster management.

In order to use an information system in case of disaster, it is essential that the system is the one used commonly between ordinary duties at normal times and emergency duties at the time of disaster. At the time of disaster, efficient operations are expected for the functions necessary for taking counter measures; any other extra functions only reduce the operation efficiency. Accordingly, on the basis of temporal and spatial information management, a integrated system is expected to be built which is capable of handling disaster information, by employing a system structure that contains the addresses and names of the residents, and by making such responses in emergency as partially limiting the normally used functions.

As shown in **Figure 2**, even if a costly exclusive system is built as a disaster prevention system, "unexpected situations" take place in most cases, preventing the demonstration of the functions originally assumed. A large-scale disaster may destroy disaster prevention systems as well as making victims out of the operators in charge. Under such circumstances especially, a fully functioning disaster prevention system is necessary. In addition to the problems of hardware for the system, an examination is essential on the software, deciding the way that a method of managing regional information should be. A processing method is sought after in which



disaster data processing is grasped as a continuity to ordinary duties with emphasis placed on cost effectiveness. It seems to be the answer to take the disaster as spatial information. With computers used, it is possible to build an information system that is provided with a three-dimensional space containing names and addresses and that is also capable of time description. The requirements for this system may be summarized as follows:

1) Mobile information system:

It need to be workable even under an unexpected unstable operating environment. Additionally, it should be capable of interlocking with stationary systems if situation permits.

2) System operable by non-specialists:

Human resources being limited in a stricken area, a system is desirable that is easy to operate by anyone having experience in using a calculator.

3) System used in normal times:

A system unusable for ordinary duties is economically inefficient and is limited in the adaptation to circumstances and the conformity to ready use.

4) Interlocking with plural systems:

A system is desired that is self-contained distributed type and usable for coordinated operation.

5) Latest area database:

An area database is required that is controlled by each local government. The storage of backup data may be carried out jointly with other local governments. For example, such an idea seems to be effective as database is mutually maintained between local governments with sister-city affiliation and mutually supported in case of emergency.

## Figure 2 Requirements for disaster management GIS

These requirements can be satisfied with a system whose basis is

personal computers used in ordinary duties. Personal computers are such that a mobile system in series has been marketed and that a number of people have experiences in using it. In municipal offices for example, the introduction of personal computers has been well under way so that the continuity may be advantageously maintained between normal situation and emergency.

#### **4. GIS for three-dimensionally spatial and temporal management**

The purpose of the geographic information processing is to grasp the situation of the stricken area and to enable proper judgment. For that purpose, a conception of information processing is necessary that is beyond a map premised on a planar description.

In **Figure 3**, the conception of a system is shown which is free from the descriptive restrictions of a map and which is capable of utilizing computers. The characteristic of this method is the structuring of a model of the actual area (area model) in a computer. In other words, the method is to express the area condition with numerical data that can be processed by a computer. The actual world is spread in the three-dimensional space and variable in time. Therefore, street margins or the positions of houses for example are recorded on their three-dimensional loci, while their numerical values are expressed as survey data with required precision regardless of the reduced scale of the map.

#### **Figure 3 Conception of 3-dimensional spatial temporal GIS.**

In order to build this area model, the map prepared by surveying the subject area can be used as a good design drawing. In addition, various statistical data, survey data, land registers, etc., are also integrated as the information descriptive of the model. Under such integrated information processing, the following added values may be anticipated:

1) Since this model is provided with the subject area numerically described, it is possible to output a map separately by purpose through a virtual graphic, to analyze or express the topography three-dimensionally, and so on.

Further, comprehensive management and comparison are possible concerning the underground public facilities or the condition of the stricken area, etc.

2) Through the integrated management of the information which is conventionally overlapped in multiples, the mutual utilization of the information is made possible, enabling the elimination of data discrepancies, or reducing the amount of information to be managed. As a result, an efficient processing is possible with a small hardware.

3) It used to be necessary to renew the database in an expensive way through the duplication of each original drawing. In the new system, the duplicating renewal work is eliminated, greatly reducing the man-hour of the work.

4) The model of each area is described in consideration of a rotary ellipsoid (spherical body) for the specified area; therefore, consistency is feasible with a measured data such as satellite photographs.

## **5. Time management for spatial database**

The maintenance control of the spatial data describing the areas can be realized through the time management for each object. If each object is under the time management, the data can be renewed as a change takes place perpetually.

At the time of confirming a construction, a person in charge in a local government can easily input the subject housing data. Renewal in real time is possible unlike the conventional paper map base in which periodic renewal was indispensable manually by specialists. Moreover, as a map required at a point in time can be outputted at the scene of service in a local government, the maintenance of paper maps is no longer necessary. Input errors by a field worker can be easily corrected by reversing the time for a little while back and confirming it. If need be, only the changed portions may be matched to the aerial photograph so as to assure the positional accuracy.

The initial database can be prepared with more accuracy correlatively by inputting the conventional survey data integrally. Furthermore, it is expected that objects written on the paper map in a

number of duplications can be replaced with one only inputting, greatly saving manpower. The positional accuracy may be increased with each integration of data. It is necessary to have a "growing database" with history efficiently maintained both in positional accuracy and contents.

If the database is such as renewed through daily duties, it will be provided with a description immediately before the outbreak of emergency. In addition, the exchange of information is easily realized by recording rapid changes and by mutually comparing various data, simultaneously eliminating the duplication of data input.

## **6. Development of DiMSIS**

DiMSIS has been developed for the purpose of organizing disaster data and demonstrated its effect for example on accepting applications for demolition and/or removal of collapsed houses. This system had prospects of being applied to house information management at normal times. Accordingly, the system was expanded so as to be capable of coping with emergency. An "emergency mode" was provided in the functions at normal times controlling fixed properties like houses and lands. The emergency mode is made ready by giving an instruction through icons normally selectable. It is so structured that, with the emergency mode actuated, ordinary requirements is processed by operating in accordance with the guidance for the operation environment.

In general, the purpose of the system is different depending on where it is used.

### **1) Headquarters for countermeasures:**

It is required to judge the overall situation and to give instructions to the field. The judgment of the situation must be made in reference to the changing situation and on the basis of the data gathered at normal times including the characteristics and dangers of the places.

### **2) Shelters:**

In the shelters, it is necessary to call over the names of the evacuees and to extract the vacant zones with no evacuees. For that purpose, it is effective to mark on the map automatically the houses

confirmed by the names or the locations and to make a list.

### 3) Actual field

In the stricken field, gathering of information and report to the headquarters are required. In order to gather the changing information, it is effective to utilize a graphic data related to positions. Accordingly, positions for photographing are inputted in the map. Since instantaneousness is more emphasized than the picture quality, a digital camera is effective.

The effectiveness of this processing has been proved in the disaster prevention training (June 12, 1996) in Nagata Ward, Kobe City.

## 7. Conclusion

The GIS is desired which takes the disaster information processing as continuity to normal duties and which attaches great importance to cost effectiveness. The answer conceivably, is to deal with disaster as spatial information. The area management by the names and addresses is a rational system based on the know-how for many years. In the information management premised on the use of electronic information equipment in addition to paper, it is possible to build a temporal and spatial information system incorporating the above conventional information system.

Problems have been pointed out such as the method and cost of preparing geographic data. The basic problem is that the conventional information processing by the map is on the assumption that the database is periodically renewed so as to reconstruct the information stored until that point. This problem can be solved by pointing to the structuring of the GIS which is capable of storing area information as the temporal and spatial information through normal duties. The prospects are bright that this next generation type GIS can be fully operated by inexpensive personal computers with the preparation of spatial data realized through the integration of information without a great deal of special cost.

It is essential to recognize that the information processed as disaster information is equivalent to that of normal times. Inquiry after the safety of people corresponds to the move management of the residents; removal of collapsed houses corresponds to the control of industrial waste and the

management of fixed properties disaster prevention plan corresponds to city planning, etc. Thus, the processing of disaster information is possible that is directly connected to the normal duties and ordinary use of a local government.

## **8. Acknowledgments**

The authors would like to acknowledge the support of the people concerned in the Nagata Ward Office including the Town Development Section, Municipal Office and Fire Department of the City of Kobe, who kindly provided the actual field of study on the occurrence of the Hanshin-Awaji Earthquake and who made the verification of this study possible. The authors also wish to thank various enterprises and the students mainly of Kyoto University and Nara University for the data structuring and the examination of the experiment system (DiMSIS).

*UNCRD 25<sup>th</sup> Anniversary Commemorative Programme*  
WORKSHOP ON GIS FOR DISASTER MANAGEMENT

**PROGRAMME**

**12 December 1996**

Chairperson: **H. Taniguchi**, National Expert, UNCRD

**9:30 Opening Address and Keynote Speech**

*Development of the Computer Aided Disaster Management System for Local Governments (CADMaS)*

by **Yujiro Ogawa**, Disaster Management Planner, UNCRD

**10:00 Evaluation of Damages Caused by Earthquakes Using Satellite Data and its Application to Seismic Disaster Management**

by **Masaki Murakami**, Head of Geodetic Research and Development Office, Geographical Survey Institute, Ministry of Construction,

**10:40 Analysis on Damage Areas of the Great Hanshin – Awaji Earthquake using GIS**

by **Bambang Rudyanto**, UN Researcher, UNCRD

**11:20 Construction of Strong Ground Motion Net Work and its Application to Seismic Disaster Management**

by **Shigeo Kinoshita**, Head of Earthquake and Volcanic Disaster Prevention Laboratory, National Research Institute for Earth Science and Disaster Prevention, Science and Technology Agency

**12:00 Lunch Break**

**13:30 Disaster and Environment Monitoring using Remote Sensing data and GIS Technology in Mongolia**

by **Bayasgalan Barkhuu**, General Director, “ORCHLON-EARTH” Co., Ltd, Mongolia

**14:10 An Alternative Methodology for Seismic Risk Analysis and Assessment in Large Urban Centers**

by **Carlos E. Montoya-Dulche**, Researcher, National Centre for Disaster Prevention (CENAPRED), Mexico

**14:50 Development of Disaster Management Special Information System (DiMSIS) based on 3-Dimensional Temporal Geographic Information System and its Application to Administrative Database of Local Government**

by **Shigeru Kakumoto**, Visiting Associate Professor, Disaster Prevention Research Institute, Kyoto University

**15:30 Coffee Break**

**16:00 Discussion:**

Chairperson: **Y. Ogawa**

**17:00 Closing Address**

by **Hideki Kaji**, Director, UNCRD



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