Development of the Disaster Information System(DIS/Earthquakes)

by

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ABSTRACT

Utilizing the experiences of the Great Hanshin-Awaji Earthquake, the National Land Agency has been promoting the development of the Disaster Information System/Earthquakes (DIS) which uses the Geographic Information System (GIS). This system is expected to provide quick and appropriate decision making in all three phases, "preparation", "emergency measures" and "recovery/rehabilitation". Since April 1996, the National Land Agency has been operating the Early Estimation System (EES) which automatically estimates the scale of damage caused by an earthquake using the very limited information available immediately after an earthquake occurs. This system began operating in April 1996, and over the period of one year, was activated 41 times by earthquakes of seismic intensity 4 or greater.

Key Words : the Great Hanshin-Awaji Earthquake
the Disaster Information System(DIS),
the Early Estimation System(EES),

I BACKGROUND

I-1 Impact of The Great Hanshin-Awaji Earthquake

The Great Hanshin-Awaji Earthquake, which occurred right under the city of Kobe on January 17, 1995, again showed the importance of rapid response activities by the national government, particularly the importance of estimating damage immediately after an earthquake.

If organizations concerned with disaster prevention have numerical map and geographical location data and a system that combines this data for quick and efficient application, they should be able to quickly determine the state of damage, and support rescue and recovery activities quickly and effectively.

Based on this experience, the National Land Agency has been promoting preparation of a Disaster Information System by utilizing Geographic Information System (GIS) that manages information on topography, ground conditions, population, building stock, disaster response facilities, etc., connected to digital maps on a computer.

I-2 Basic framework of the new disaster prevention

The difficulty encountered in collecting appropriate information after the Great Hanshin-Awaji Earthquake reemphasized the importance of information. How to collect, put in order and analyze information efficiently have become major factors in recognizing the necessity of building a

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new system.

The new basic plan which was amended in July 1995 considers the importance of information in the following three stages: prevention, emergency measures and recovery/rehabilitation. It shall promote the construction of geographic information systems to support the realization of disaster-preventive measures.. It also states that the on-line database network shall be construct.

Certain activities are specifically indicated in the new plan. They are utilization and application of geographic information systems, monitoring systems, etc. after the occurrence of a disaster in order to quickly analyze the scale of damage, to collect and comprehend information on primary & general damage and on emergency measures so that it can be passed on to relevant organizations, and to assure that appropriate measures are taken to establish necessary communications.

I-3 Toward the advanced information society

For the past three years or so, there has been a strong trend toward the advanced information society. People are becoming increasingly more aware that something has to be done. There is the personal computer boom. More and more people are beginning to use personal computers, and such computers are increasing their capabilities as well as their kinds day by day.

Maintenance of information on earthquake disasters should be systematically carried out by using geographical information systems which have been making remarkable development in recent years. It is said that 1994, the year before The Great Hanshin-Awaji Earthquake, was the beginning of the advanced information society in Japan, and the people started to discuss the concept of a "Japan Information Super-Highway."

Because of digitalization resulting from sophisticated uses of information, and of technological development epitomized by the downsizing of the calculator the Geographic Information System (GIS) has been making rapid progress in application technology, hardware and software. At present, various kinds of numerical maps are being prepared by concerned organizations.

Handling of a huge amount of information has been made possible by development of data processing technology by computers and communications technology, due to rapid progress in technical innovation, such as optical fiber and communication satellites.

In short, we have reached the stage where we are technically capable of constructing large-scale network systems, such as a disaster information system, that allow us to process a large amount of map data by linking many relevant organizations. Under this situation, the importance of information has been recognized, and the development of the DIS/Earthquakes was initiated.

II DIS/EARTHQUAKES - ITS OUTLINE AND CURRENT STATUS

II-1 Outline of the system

To develop an earthquake disaster information system (DIS/Earthquakes), the National Land Agency established a committee composed of specialists on earthquake disasters and their preventive systems, and persons from related ministries and agencies. References are being made to similar systems, both academic and practical, which have been or are being developed in the U.S.

As shown in Attachment 1, DIS/Earthquakes focuses on three stages of an earthquake disaster. They are emergency period, recovery/rehabilitation period, and preparation period for the next disaster. This system is expected to effectively support quick and appropriate decision making by the organizations concerned.

DIS/Earthquakes is composed of a Disaster Information Control System, which provides a base for analysis, and subsystems that perform actual analysis. The Disaster Information Control System accommodates and manages the information needed for operation of each subsystem in DIS/Earthquakes. As shown in Attachment 2, its data base includes map data on administrative organizations, public facilities, roads, organizations and facilities for disaster prevention, etc.

The National Land Agency places the highest priority to the communications immediately following the occurrence of an earthquake. The Early (Damage) Estimation System (EES) has been in operation since April 1996. This system automatically estimates the scale of damage and indicates the initial activities required within 30 minutes after the occurrence of the earthquake by using very limited information.

The Earthquake Damage Information System continuously collects transient information on damage and recovery concerning public facilities, lifelines, etc. The data base is updated accordingly and the information is shown on maps to assist decision making. The system will also provide information on damage to roads, railways and lifelines to the organizations concerned so that they can effectively utilize it in taking emergency operational measures.

The Emergency Measures Support System utilizes the output from EES and the Earthquake Damage Information System to support search and rescue activities and to help optimize the distribution of relief materials. According to different emergency measures, there will be different systems for transportation, rescue/medical attention, evacuation, and volunteers.

As time passes, recovery/rehabilitation measures become more important, and here comes the Recovery/Rehabilitation Measures Support System, which provides information to support the establishment of recovery and rehabilitation plans at various levels, and to help manage their progress.

The abovementioned systems respond to the activities in the post-earthquake period. However, preparation for the next disaster is also important for the National Land Agency.

The Earthquake Damage Estimation System will forecast the extent of damage due to a future earthquake by map information data base. It will be used to plan and establish various disaster measures before the next one comes.

The Earthquake Disaster Prevention Facilities Preparation Plan Support System will be utilized to select possible sites for emergency facilities. It will also be useful to determine kinds of facilities to be prepared by simulating the effectiveness of different measures for different earthquakes.

III EARLY ESTIMATION SYSTEM (EES)

III-1 Purpose and outline of EES development

Earthquake damage estimation is often used as the initial condition for contingency planning. Such an estimation is based on a compilation of a number of R&D results integrated into a comprehensive system. Such a system may be further integrated to estimate the macroscopic scale of damage and the extent of the affected area by using a very limited amount of input information. EES provides a real-time estimation of the numbers of damaged buildings and casualties. The system has been developed to provide information that contributes to quick and appropriate judgment for making decisions concerning emergency measures when there is only limited information available immediately after the occurrence of an earthquake.

Some of the features of EES are as follows:

- EES covers the entire country,
- EES estimates only damage to buildings and casualties caused by earthquake vibration at the municipality level. It does not estimate damage caused by fires, aftershocks, etc.,
- EES automatically receives seismic information from the Japan Meteorological Agency and is activated when JMA intensity greater than 4 is detected at one or more seismic intensity observation points throughout the country,
- Under the conditions cited above, EES provides the results of estimation with 30 minutes after the occurrence of an earthquake,
- Unlike standard earthquake damage estimation, EES operates with a small computer of the size of work stations.

III-2 System configuration and estimation methods

EES is composed of processing equipment (database server units), terminal equipment for display (clients), printers, etc., all of which are easily available on the market. The equipment in normal service at the main office of the National Land Agency is augmented by stand-by equipment at the Greater Tachikawa Contingency Station. Thus, if there is a problem with one system, the other system takes over immediately.

The National Land Agency is connected by LAN with simultaneous reporting equipment to receive earthquake information from the Meteorological Agency and to transfer it to the processing equipment. The results of estimation by the processing equipment are automatically outputted to the terminal equipment for display.

The following summarizes the flow for damage estimation:

- EES is automatically activated as described above,
- The seismic data is combined with surface soil and topographical data to estimate the distribution of ground motion severity,
- Based on the estimated distribution of ground motion severity, available building data is utilized to estimate the damage to buildings,
- Available population data is used to estimate causalities caused by building destruction, and
- The results are automatically shown on a display terminal.

Earthquake information from the Meteorological Agency is transmitted within about 10 minutes after it is generated and the estimation of damage is completed in 5 - 20 minutes according to the size of the area affected. Back-up functions are provided for manual input of data when the data cannot be automatically received.

III-3 Outline of the logic for each estimation process

III-3-1 Intensity and estimation grid

For estimation of earthquake damage, JMA seismic intensity is used to represent the severity of ground shaking. It is received in real time from the Meteorological Agency as the initial earthquake information. From seismic intensity observed at the ground surface and consideration of influence of geological features of the earth's crust, it should be possible to estimate the isoplethic curve (contour) for speed distribution of an earthquake. From the estimated contour, intensity distribution on the ground surface is computed taking into account the properties of the surface layers again.(see attachment 4)

The National Land Numeric Information Tertiary Mesh (1km^2 mesh) is used. The properties of the surface layers are classified into 13 types based on geological and topographical data of each grid, from which amplification factors are determined.

By assuming a relationship between the estimated seismic intensity and the building damage, the damage to buildings in each grid is estimated, and the number of damaged houses is integrated for each municipality. Buildings are classified as wooden and non-wooden buildings, and the number of damaged houses is estimated for each of them.

III-3-2 Wooden building damage

The building areas in a municipality was first obtained for different age groups and they were divided by the average building area per house of the municipality to determine the number of buildings in different age groups in the municipality. These numbers were distributed to each grid in proportion to the night-time population to estimate the number of buildings in each grid.

Buildings were classified into two age groups according to whether or not they were built after 1960, when a major revision of the Building Standards Act was implemented to specify the quantity of framework and walls required.

The whole area of Japan was divided into three groups according to the snow load adopted for structural design. The surface soil properties were regrouped into two, soft and hard, based on the predominant periods computed by using the 13 types previously mentioned.

Therefore, the damage factor for wooden buildings was expressed in terms of seismic intensity, building age, snow load level, and surface soil property. Non-linear response analysis was performed for all the combinations of the four parameters. The number of collapsed buildings was then obtained by multiplying the number of houses in each category by the collapse ratio of the houses in each category.

III-3-3 Non-wooden building damage

Non-wooden buildings were classified by only building age according to whether or not they were built after 1981, when the new Anti-Earthquake Design Act was introduced.

The damage factor for non-wooden buildings was expressed in terms of seismic intensity, building age, and surface soil property. The damage level for non-wooden buildings in each category was estimated by those encountered in the Hanshin-Awaji Earthquake. The collapse ratio for non-wooden buildings built in or after 1982 was assumed to be zero.

III-3-4 Casualties due to building collapse

The number of dead caused by the collapse of wooden and non-wooden buildings was estimated for each municipality. The estimation took into account the time of earthquake occurrence. The change in the numbers of people staying in different "places" was determined from the temporal change of the population during the night-time and the day-time. Population at a certain time of a day was estimated based on the results of personal travel surveys performed in representative cities, with the "places" classified as houses, other facilities, and transient points.

Since it was difficult to develop a logical model to determine the relation between casualties and wooden building, statistical regression of historical earthquake data was made. Data from recent five earthquakes which caused more than 300 dead were used by assuming a linear relation between the two quantities.

The number of dead caused by wooden building collapse was assumed to be proportional to the number of collapsed wooden buildings and the number of people in them.

It is assumed that dead caused by the collapse of non-wooden building has a linear relation with the number of people in those buildings. This parameter (rate of damage) is estimated based on the data on building collapses during The Great Hanshin-Awaji Earthquake and an accident that recently occurred in Korea.

III-4 Implementation

When emergency measures are taken to respond to damage caused by an earthquake, it is best to try to take proper and efficient measures based on information from the actual site. However, in the case of The 1995 Great Hanshin-Awaji Earthquake, the affected area was in confusion and it was impossible to obtain accurate information from the site. In a large earthquake, the affected area extends over surrounding municipalities, and it is extremely difficult to obtain information at the site. There is also a high probability that the means of information transfer will be destroyed.

EES, however, estimates the scale and the areal extent of damage by only using seismic intensity data immediately following an earthquake. EES places emphasis on the importance of overall damage caused by the earthquake. Thus, although it may not be possible to obtain damage information at the site, the estimated data given within 30 minutes after the earthquake occurrence may be used to prevent delay in initial responses and to help initiate quick and appropriate initial actions and emergency measures.

If EES had been available in the case of The Great Hanshin-Awaji Earthquake, estimation would have been completed within about 15 minutes after the JMA data was received, and estimation results would have been obtained within about 25 minutes after the earthquake occurred. (For a smaller earthquake, time required for estimation would even be shorter.) EES's preliminary estimation was found to give "About 100,000 collapsed buildings and about 4,000 dead". The distribution of seismic intensities is shown in Attachment 5.

A year has passed since the system began operating in April 1996. Over this period, it has been activated by earthquakes above intensity IV 41 times, and has generated results within 15 minutes. Over this period, 13 earthquakes above intensity V occurred. The earthquake in the Satsuma region of Kagoshima Prefecture (southwestern Kyushu) on March 26, 1997 registered a magnitude of 6.2, and had a maximum seismic intensity of "strong 5." The distribution of seismic intensities for this earthquake, as estimated by EES, is shown in Attachment 6. In these instances, the system was able to provide qualitative assessments of the state of damage, and by acting as an early source of information contributed effectively to the start-up phases of the disaster prevention systems. At around seismic intensity V, the graph representing rates of damage has just begun to be expressed. This means that the level of error is greater than the level of data, making it difficult to assess damage quantitatively.

We believe that the reason estimates of damage are higher than actual damage is because verification has been taking place in large urban areas and in regions in northern Japan. There is a need to improve the accuracy of the system by gradually adding more verifications etc. from regional cities in southern Japan.

In any case, the EES has steadily achieved results in the year since it has been in operation.

IV CONCLUSIONS

Regarding the DIS, we are developing GIS maps and carrying out the development of an emergency measures support system for the southern Kanto region, where an earthquake striking directly beneath large urban areas is believed to be imminent. Hereafter, as development of the overall system proceeds, there is a need to respond to the following kinds of issues.

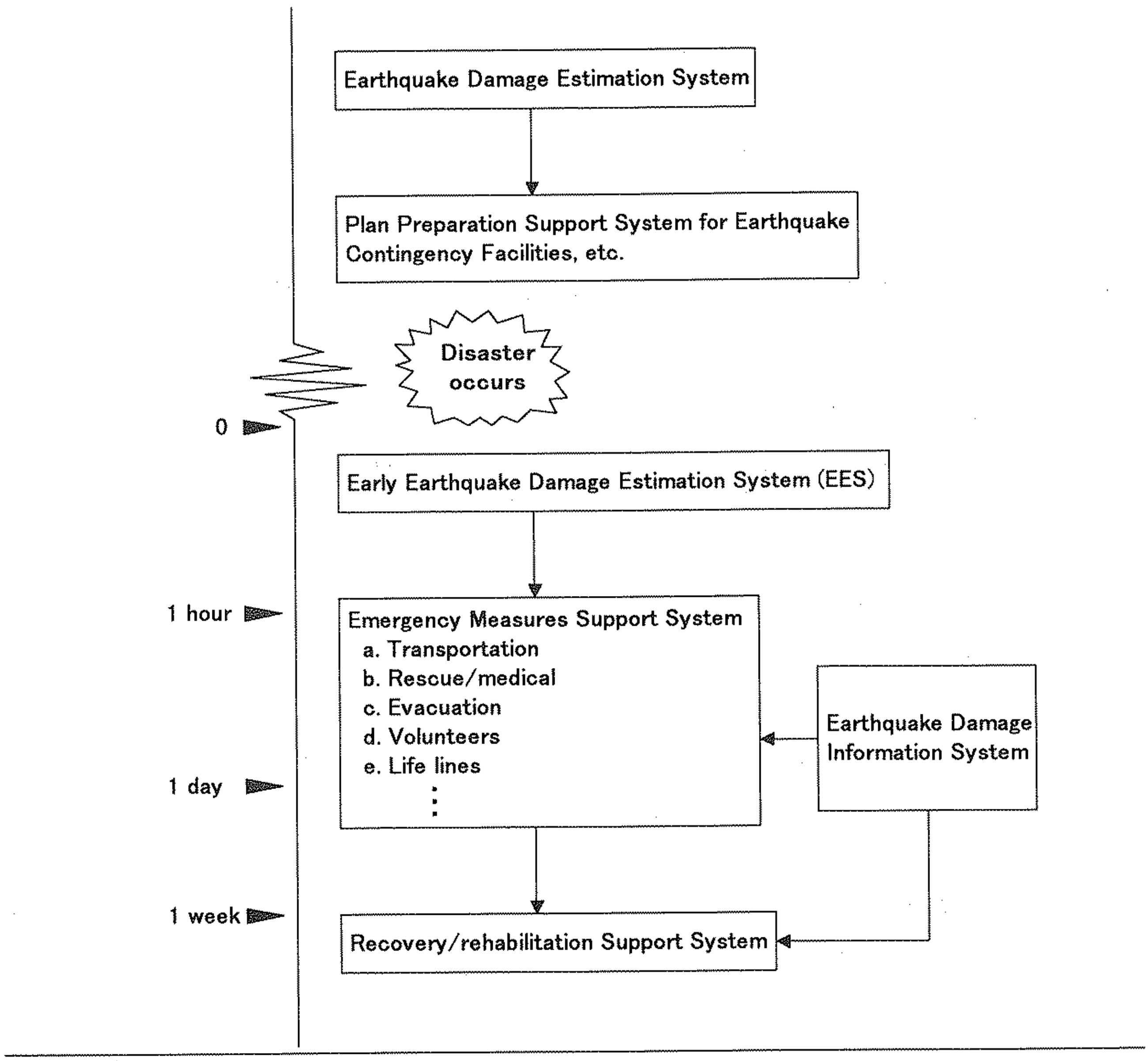
In the case of natural disaster mitigation, it is becoming increasingly important to devise a means of mutual collaboration among related organizations for the effective use of the DIS/Earthquakes. The National Land Agency is willing to advance development of a network with related agencies and local municipalities through LANs using central contingency radios to provide accurate information in real time.

After a disaster, this information will control all countermeasures, so it is necessary to construct an information collection system that responds to expected interruptions and complications of information communication disruption. Therefore, the intent is to strengthen the information collection system by effectively utilizing such communication measures as portable information equipment and the Internet, which has recently been developing remarkably, to enable direct input of damage information sent from the actual site, in addition to information collection utilizing aircraft, etc.

For total preparation of the DIS/Earthquakes, there remain the problems of money and time required to prepare the map data, which is the foundation of the system, and more detailed disaster prevention related data. The National Land Agency is expecting to complete the development of DIS/Earthquakes in five years and hopes that DIS/Earthquakes will become an effective system to be utilized for executing as well as planning contingency measures.

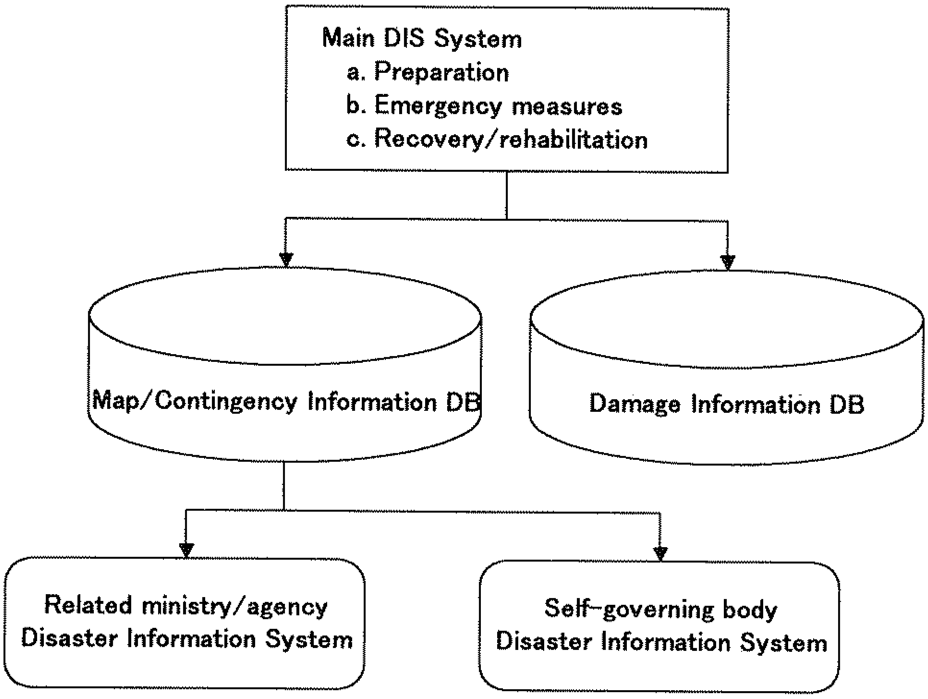
Attachment 1

Composition of DIS (Disaster Information System/Earthquake)



Attachment 2

System Image of DIS (Disaster Information System/Earthquake)



Detailed display functions

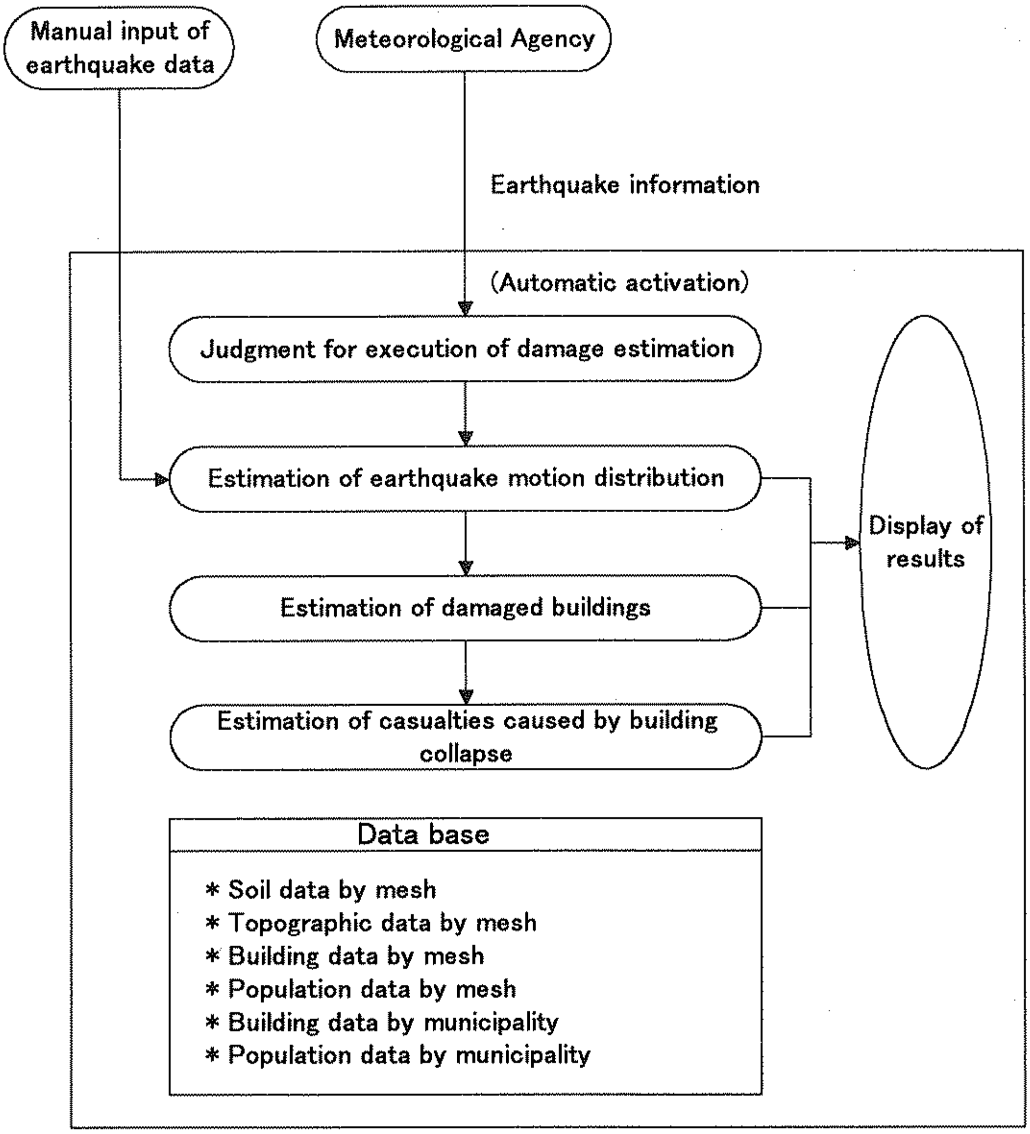
* Accurately displays individual buildings using map data at a maximum scale of 1/2500
* Displays facilities directly involved with disaster prevention, including fire departments, police departments, schools, food storage locations and locations of relief items
* Displays facilities related to emergency transportation, including roads, airports and harbors

Powerful analysis functions

* Sub-systems provide powerful analysis functions
* Sub-systems can be added to respond to new needs as they occur.

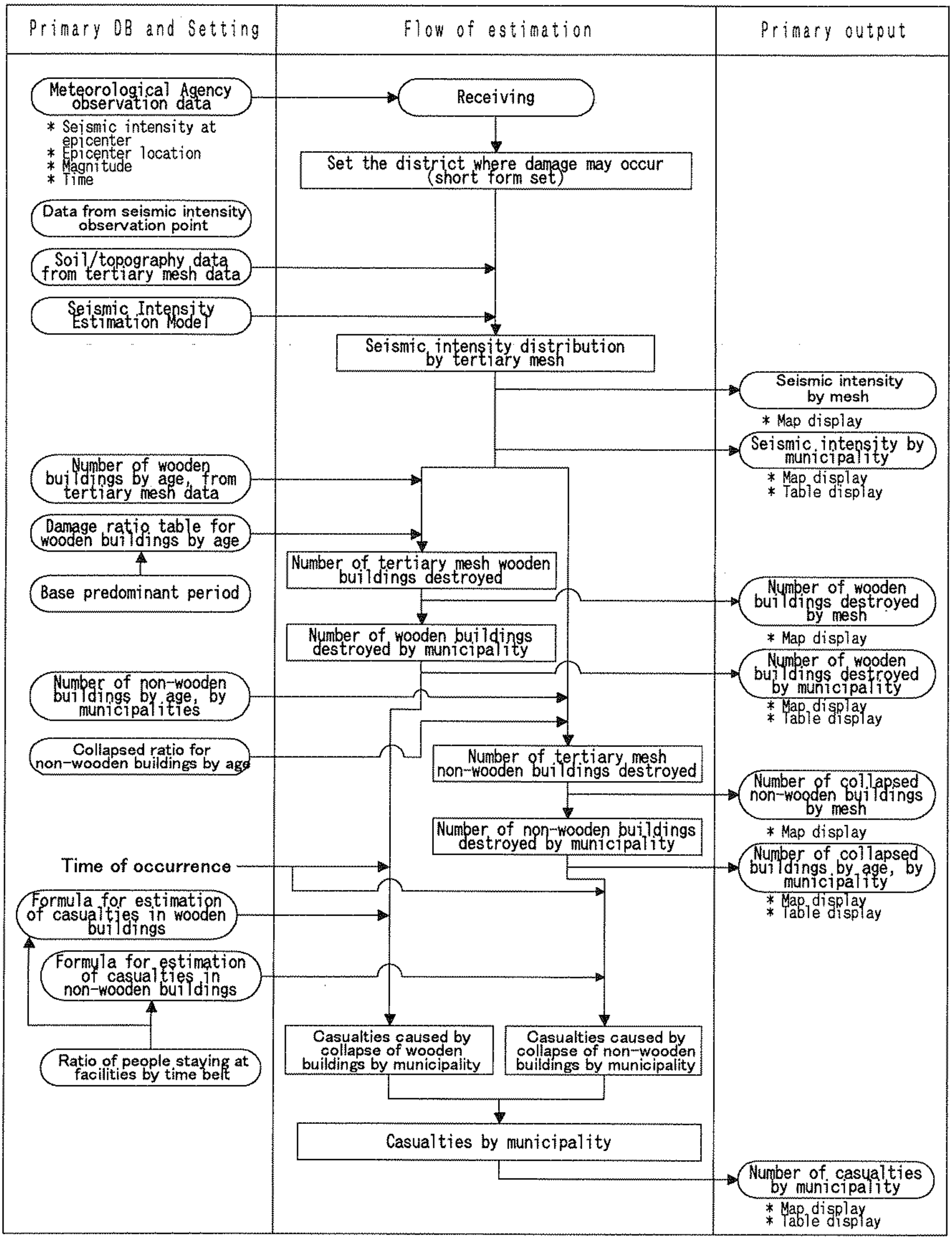
Attachment 3

Flow of Earthquake Damage Estimation

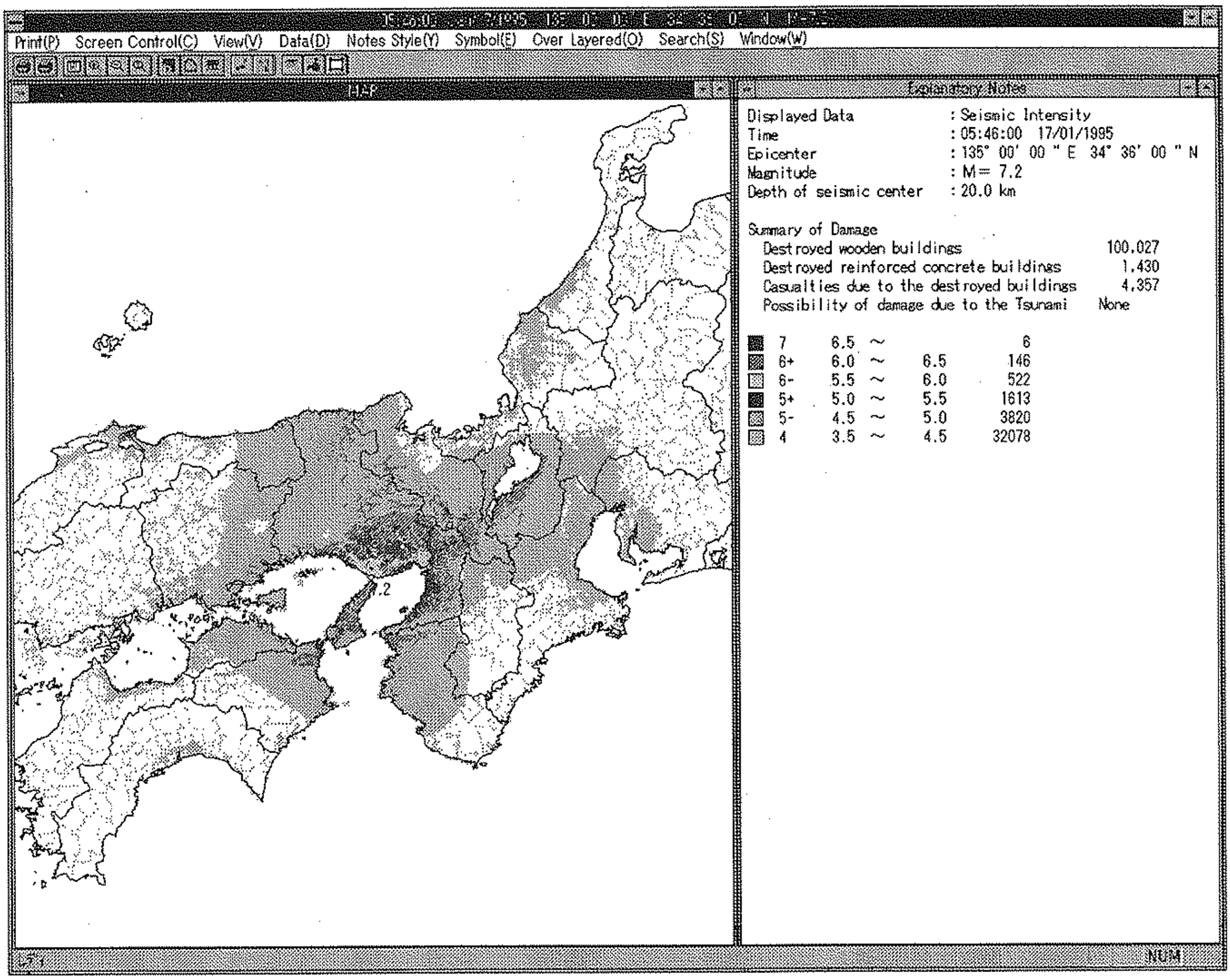


Attachment 4

Flow of Earthquake Damage Estimation



The estimated result of distribution of seismic intensities in the case of the Great Hanshin-Awaji Earthquake



The estimated result of distribution of seismic intensities in the case of the earthquake in the Satsuma Region of Kagoshima Prefecture on March 26th, 1997