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"Partnerships for a Safer World
in the 21st Century"



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Building a Culture of Prevention



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University**

Coping study on

Technology for Disaster Reduction

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"Partnerships for a safer world in the 21st century"



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1. Future of Disaster Response

Kawasaki is a highly industrial coastal city in Japan with a population about 1.2 million. It is located south-west of Tokyo across the Tamagawa river, bordered on the south-west side by Yokohama city. The city covers a 30 km long stretch of land, 5 km wide, from the south-east to the north-west with its south-east edge forming a coastal area along Tokyo bay. On a winter weekday evening at 5 p.m. an earthquake of magnitude of 7.9 strikes Sagami bay in a repeat of 1923 Kanto earthquake. Immediately after the earthquake, the Urgent Earthquake Detection and Alarm System (UrEDAS) of the Railway Technical Research Institute (RTRI) detects the arrival of P-wave from its own observation network and determines the magnitude and location of the earthquake instantly. Using the information it stops the bullet trains (shinkansen) which travel at around 250 km or above on the Tokyo, Osaka line. Simultaneously, RTRI's Hazard Estimation and Restoration Aid System (HERAS) goes into operation to collect damage estimations relating to railway systems. The HERAS system is capable of providing damage information on railways and associated facilities in about 5 min after an event. This information will be used in the recovery and restoration operations to the railway systems. At the same time, the Seismic Information Gathering and Network ALert system (SIGNAL) of Tokyo Gas company goes in operation shutting off gas supply automatically in areas where ground shaking exceeded a prescribed threshold, in order to prevent fires from secondary damage such as gas leaks.

On the government side, the damage assessment and support system of Kawasaki City, which became operational in 1994, is activated. The system gathers real time earthquake information from a dense observation network, calculates ground motion and estimates probable damage by combining the ground motion estimates with the information from a Geographic Information System (GIS) consisting of soil, land cover, infrastructure, population distribution, housing conditions and lifeline information. The estimated damage due to this earthquake will be on the order of 1.3 trillion yen, with about 90% of the 33 thousand wooden buildings predicted to be destroyed by fire at the prevailing wind speed of 6m/s from NNW direction. Fatalities will be up to 3120, road damages would be up to about 250 locations. There would also be widespread destruction to lifeline systems such as water supply and gas supply, which would require more than a month for complete recovery.

This is a future earthquake scenario Kawasaki City is preparing for. The disaster information and response systems as described above, giving the locations and possible damage immediately in the aftermath of a large earthquake is of immense value to the officials in charge of disaster management. Countermeasures for earthquakes should be of preventive in nature and should be planned and implemented in advance. However, it is not possible to fully prepare in advance for all possibilities and information systems such as the one described above becomes indispensable in managing complex disasters. The Kobe earthquake in 1995 only reiterated the importance of having a quick grasp of what has happened to a given region so that effective responses can be made. Kawasaki was the first Japanese City to introduce such a system, and there exists several such systems for different parts of the country and these are implemented by different organisations (for example Disaster Information System [DIS] by the National Land Agency of Japan) have been implemented. In USA, HASUS (Hazard USA) developed by FEMA, and the Early Post-Earthquake Damage Assessment Tool (EPEDAT) developed for building and lifeline damage assessment in Southern California, are a couple of such systems that are either in operation or are currently in the development. These systems would play a key role in the future not only helping in better response and recovery, but also as planning tools for identifying and implementing optimum disaster mitigation strategies. At present, the systems designed to carry out a single task after assessing the severity of a disaster, such as UREDAS and SIGNAL, performs well. Other more complex systems looking for optimal responses are still at the initial stage of providing information to different sectors of society involved in the response. Future directions of these decision support systems would be to implement interaction between different organisations and individuals and to provide capability to assess the impact of different mitigation and response strategies.

2. Technology and Disaster Reduction

Reduction of losses can be achieved in various phases of a disaster cycle; namely mitigation, preparedness, response, recovery and reconstruction. Figure 1 shows a conceptual diagram of various phases of a disaster cycle and what roles mitigation and preparedness can play in reducing total losses due to disasters. The degree of mitigation efforts in terms of disaster resilient infrastructure and land use planning determines whether a given hazard would

transform into a disaster and thus the corresponding magnitude of the resulting disaster. Preparedness measures taken before a disaster will determine the losses resulting from such event as well as time taken to recover. The reconstruction strategies adopted would determine the degree of recovery and the time taken for recovery efforts. Various technologies are available for each of these phases at varying degree of complexity and sophistication. Selection of appropriate technology and implementation of measures should be carried out

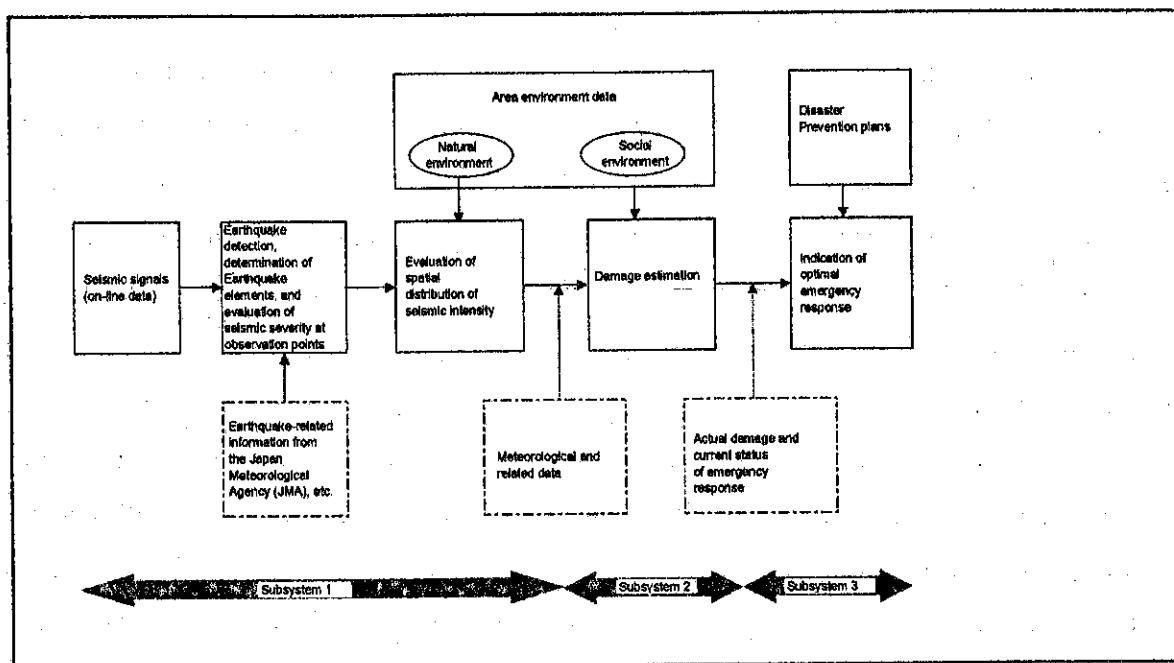


Fig 1 Outline of Kawasaki disaster information system

strategically to reduce the frequency of the disaster cycle shown in Figure 1.

Natural hazards tend to turn into disasters when a vulnerable society is affected by the hazard. The severity of the disaster is dependent on the magnitude and nature of hazard, the physical characteristics of the location and the socio-economic conditions of the society threatened, which determine the degree of vulnerability of the population.

In general it is neither feasible nor meaningful to generalise disaster reduction measures. The Kawasaki earthquake response system described above is irrelevant to the vast majority of earthquake prone cities in the developing world. Even in Japan, although there is a strong emphasis now in protecting and restoring lifeline systems in the aftermath of a disaster,

during the 25 years that followed World War II, this was not a priority issue at all. At that time, the priority was to develop the infrastructure needs of the society at least to the minimum of functional social needs. This illustrates that technologies adopted change with time as well as with the priorities of society.

Disaster cycle and countermeasures

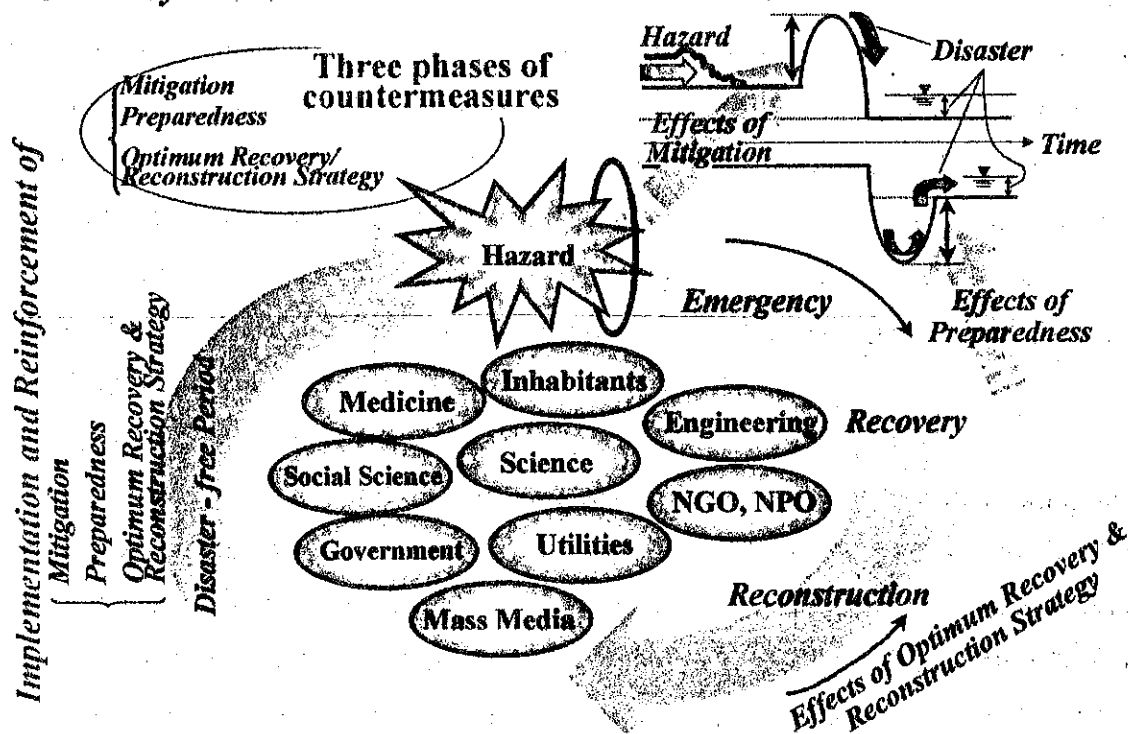


Fig 2 Disaster cycle and countermeasures

3. Functional Technology for Disaster Reduction

Technologies for disaster reduction do not necessarily mean advanced or new technologies. A more important criterion should be technology that can function adequately to support the achievement of a set of objectives within the available supporting infrastructure and resources. For a technology to function adequately, it should have institutional and resource support. Ideally, the technology should also be a part of the long term development plans capable of supporting activities other than for what it is originally selected.

The solutions to disaster reduction have to be found for each locality that can be implemented properly and maintained. At first, the purpose or the specific goals relevant to disaster reduction should be identified to avoid the technology becoming an end in itself. It is often said that it is impossible to prevent natural hazard occurrence. It is also a well accepted fact that mitigation measures are adopted to counter the disaster impacts for a given return period of hazard frequency. This time frame often has to in balance with other economic and development needs of the society. However, disaster mitigation should be viewed as an incremental process to reduce the frequency of the disaster cycle through long term planning. Countries that have been successful in reducing losses from natural disasters have achieved this success through long term commitment to reduce vulnerability by providing permanent protection from disasters; i.e. by implementing disaster resilient infrastructure and implementing disaster reducing land management practices. It is important to learn from the experience of these countries, especially the success of past preventive measures, subjected to available institutional support and resources. Figure 3 shows the capital expenditure of the Japanese government for disaster reduction. The solid line on top which remains constantly high is the expenditure on disaster reduction infrastructure such as river improvement, slope protection works, infrastructure development, etc. With this continuous expenditure a reduction of deaths due to disasters as well as declining trend in expenditure on recovery was achieved. With the reduction of disaster frequency, economic development can progress steadily and this surplus is fed back in to retrofit and strengthen infrastructure to make them more resilient against natural hazards. The technologies adopted therefore should be sustainable for such long term planning and for gradual increase of disaster mitigation capacity.

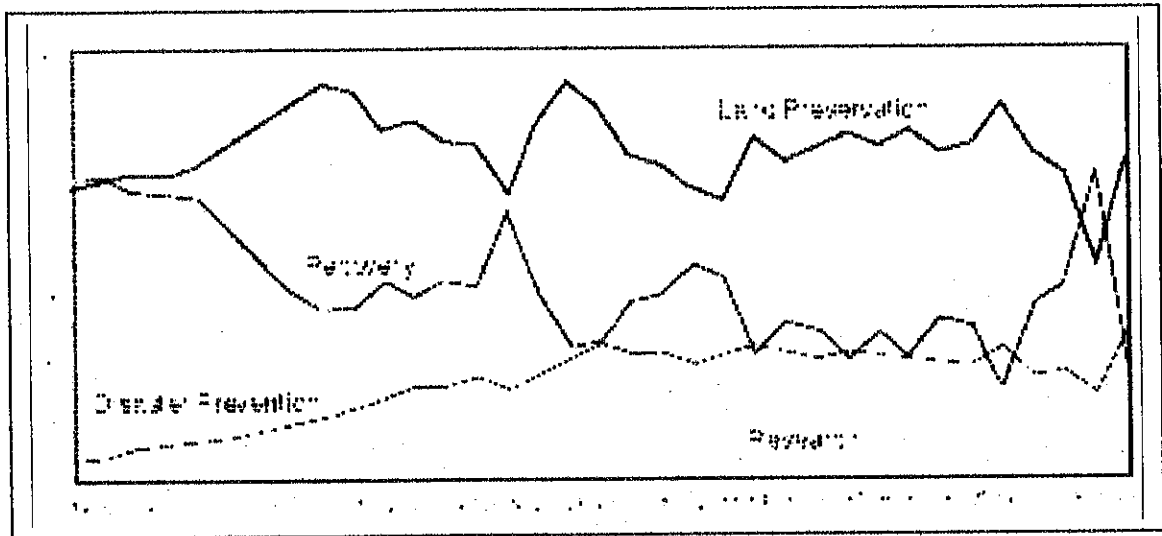


Fig 3 National Budget for Disaster Management

4. Scope of the Paper

Technology has a key role to play in the development and placement of disaster resilient infrastructure. Many new technologies that have emerged recently such as lifeline support, active control of structure in earthquake engineering, and proven technologies in the flood plain management, river improvement exist for all types of disaster reduction measures. As this is the topic of the second report of this series, the present paper will concentrate on the role of technology in the other phases of disaster reduction, namely in the preparedness, response, recovery and reconstruction as well as technologies for supporting mitigation efforts through planning.

Spurred by International Decade for Natural Disaster Reduction (IDNDR) initiative, this decade has seen a surge of applications of various technologies in natural hazards monitoring and preparedness. As the appropriateness and applicability of these technologies will vary from location to location, rather than attempting to review these individual technologies, the paper would focus on some generic technologies and their applicability in disaster mitigation.

Rapid developments in information technology and modelling have emerged as new key technological developments, which help to cope up with the complexities of disasters and deepen the understanding of natural disasters. The important feature of these technologies is that they can function at the global, national and local levels. At the global level, these technologies can pool resources available world-wide for a specific activity, such as in weather forecasting, map production, monitoring, etc. At the national level, they can be used in setting and supporting long term national disaster reduction efforts, and at the local level they can be applied to local problems directly. Two key features of these technologies are that,

1. They can immediately benefit from the new progress of the technologies anywhere in the world.
2. These technologies support a multitude of activities, especially the development process that makes it easy to harmonise disaster mitigation with development planning.

Nevertheless, notwithstanding the promise of technology, the potential of their usage is still only a promise to the vast majority of the disaster affected communities. The infrastructure, in terms of human resources as well as supporting technologies are not available for most of the communities that would benefit most from such technologies. Most of the aforementioned technologies are expensive, and it would not be possible to support them only in the field of disaster reduction. However, they are essential tools in the national development efforts and thus programs should be formulated to incorporate utilisation of such technologies both for development planning, increasing the efficiency of societies and disaster mitigation.

5. Remote Sensing in Disaster Reduction

Monitoring is essential for the detection of the onset of disasters, help in appraising a disaster situation, effective recovery and reconstruction. Due to the nature of natural disasters, often it is necessary to monitor vast areas, and airborne observation systems are the most effective for this purpose. Satellite based monitoring is one emerging option, which is becoming a viable option for monitoring from space. At the same time, continuous data gathering made possible through satellite monitoring can be used in the development planning incorporating disaster mitigation measures.

5. 1 Cyclone Detection and Warning

At the global level

The greatest success of the developments in monitoring technologies has probably been made in the cyclone damage reduction. WMO has been responsible for a global program of cyclone warning. Host of observation technologies, ranging from satellite monitoring, airborne surveillance and radar are used to track cyclones and feed information to various predictive models to increase the reliability of warning. In all countries around the globe, both human casualties and infrastructure damage has been reduced through effective monitoring and warning of cyclones.

Meteorological satellites play the main role of detection and tracking of cyclones as they form and move over the ocean. Nearing landfall, cyclone tracking is taken over by the weather radar. Under the WMO umbrella, weather organisations around the world co-operate and share technological developments in a well-established cyclone detection and warning program.

At national and local level

At the national level the main responsibility with regards to forecasts is to contribute as well as benefit from the global observation, modelling and warning capabilities, and to develop complementary facilities to increase the reliability of warnings within the country's jurisdiction.

The improvements to be carried out mainly remain in the dissemination of early warnings and response phases. This is a complex problem, not completely solved in both developed and developing countries. The problems exist in effective communication of the warnings with the still considerable uncertainty and inaccuracies inherent in the warnings themselves. The warning and responses have to be co-ordinated among various agencies and the general public in order to maximise the benefits of its use.

The compilation of past experiences in identifying vulnerable areas for mitigation measures is another important task within the framework of national and local planning. More than the technology itself, it is the use of available information in dissemination, response and mitigation that need improvement.

5.2 Weather Radar

A weather radar or radar rain gauge is a rainfall observation system using radar. The observation method using radar is based on an entirely different principle from the conventional ground rain-gauge observation. The observed value of a radar is the electric power backscattered from a group of rain drops in a certain volume of air. The extent of the area unit vary with the radar resolution and may be in the order of 2 km x 2 km to 500 m x 500 m. The weather radar can provide a quick estimate of rainfall density covering a large

area, and the continuous measurement capabilities of rainfall movement has been used to develop predictive models which are used for short term rainfall forecasts. However, due to the many assumptions used in the conversion of backscatter to rain intensity, accurate quantitative estimates are not possible from the measurements. Unless quite sophisticated integration and calibration techniques are used, the measurements cannot be used in the predictive models such as flood forecasting models, which require a high degree of accuracy of rainfall estimates. However, this information is quite useful in predicting rainfall ranges, such as in drainage operations and a host of similar applications.

In deploying weather radar it is important to recognise that a host of supporting technologies for calibrating the radar, interpreting measurements as well as for storage and retrieval of data, are required, and the lack of them can make expensive weather radar to be under-utilised.

5.3 Drought Monitoring

At global level

Droughts inflict the most damage to a large part of the world each year. Remote sensing is a useful tool for appraising disaster situations in drought affected areas. The main observations related to drought monitoring are carried by NOAA/AVHRR data for practical purposes, and will continue to be so for some time to come. The useful indices are, Normalised Difference Vegetation Index (NDVI), Vegetation Condition Index (VCI), Temperature condition index (TCI), Leaf area index estimated from AVHRR, biomass, surface wetness, rainfall, snow cover and temperature, estimated from SSMI sensor.

At national level

Remote sensing data cannot be used for early warning of drought disasters, though they can be used in appraising extent of drought impact. At national level the main objective is to secure food supply, mostly through international assistance within available lead-time. Where early warning of water shortage is available as sometimes the case with El-Nino forecasts, measures such as crop switching and cultivation regulation measures are adopted.

5.4 Earthquake Damage Mitigation

At global level

To be useful in damage assessment, satellites should be able to provide 1-2 m resolution with high temporal resolution. This capability is not available at present in the currently orbiting satellites though such information would be available soon through new generation of high-resolution satellites. Even if the spatial resolution is achieved, it would be difficult to achieve the high temporal resolution required for this purpose unless multiple satellites are used.

At national level

Satellites will provide general information on land cover that would support various civil engineering works for mitigation and response. Interferometry Synthetic Aperture Radar (InSAR) applications have been used to view very small (centimetre level) crustal movements that occurred during earthquakes, which contribute to enhance the understanding of the earthquake mechanism itself. GPS arrays are being used in monitoring minute earth movements though their use is still under research phase.

5.5 Fire Management

At global level

Satellite monitoring is used in fire management in two different ways. One is the identification of the potential fire risk through the estimates of combustible material volume and surface temperature. The other is the dynamic approach for real time risk assessment using meteorological and vegetation derived variables. The fire detection from satellites is carried out primarily using the reflecting material property where the black body temperature of the heated object shifts its reflectance from channel 4 region to channel 3 region. While it is possible to carry out such monitoring from anywhere in the world for any target location, due to the need for ground truth data for satellite data calibration and utilisation of the information generated, operational systems have to be implemented at the national level.

At national level

Fire management by satellite observation calls for high repeat rates, preferably at about 15 min intervals. In the Western Hemisphere, GEOS satellites, which is primarily a weather satellite, but also used in biomass detection provides such coverage in USA. In the Eastern Hemisphere, GMS satellites provide images at 1 hr repeat rates and had been used in deploying a fire detection system in the aftermath of the Indonesian forest fires.

5.6 Flood Damage Reduction

At global level

A large number of satellite sensors aboard both meteorological satellites and earth observation satellites can be used to estimate hydrological variables ranging from snow cover, water elevation, rain rate, soil moisture, solar radiation, surface albedo, land cover, flood monitoring and surface temperature. Unfortunately, none of these satellites can be used in real time flood monitoring unless the floods cover vast areas and takes many days to develop and subside such as the Oder floods in 1997 in Europe. The temporal frequency of high resolution optical sensors are too low, whereas meteorological satellites with 1-2 km resolution are too coarse to be used in the flood monitoring except for very large flooding. In most of the cases, the flooded areas would be under cloud cover limiting the usefulness of the optical satellites. On the other hand SAR sensors can penetrate clouds and can furnish finished flood maps based on SAR images some times combined with optical images taken prior to the flood event. However, the delivery times of the order of days after the acquisition still limit the applicability of space monitoring of floods to continental scale floods in flat terrain.

At national and local level

The real strength of remote sensing in flood mitigation lies in the ability to supply difficult to measure parameters to flood modelling, especially the land cover and vegetation information. Additionally satellite images may be employed to estimate the area distribution of relative rain intensity that can be calibrated with ground based rain gauge measurements. This information is also required in the development of flood risk maps.

5.7 Overview of Space Monitoring in Disaster Reduction

Often satellite remote sensing is expected to contribute in the preparedness and response phases of disaster mitigation. This means detecting onset of a disaster so that timely warning with enough certainty can be issued and once a disaster strikes and dynamic changes can be monitored so that appropriate relief measures can be taken. In the case of most of natural disasters, the present generation of satellite remote sensing does not have the spatial resolution or the frequency of coverage to achieve this. Hence, except for cyclone tracking, weather forecasting and in some initial application of fire monitoring, remote sensing data are not operationally used in disaster management.

On the other hand, remotely sensed information via satellite are making an immense contribution in the mitigation and recovery phases where the frequency of observations is not demanding. For mitigation, spatial mapping of topography, land cover, vegetation index, surface temperature, etc., are some of the fundamental information required in the development of disaster resilient infrastructure and land management. Also such information combined with mathematical simulation and forecasting models makes it possible to derive risk maps, which are invaluable for disaster preparedness. Satellite remote sensing is the only viable data source for modelling required in regional and global scales such as local area models used in weather forecasts and global circulation models for long term climatic change assessment. With the improvement of these models in climatic prediction, it may be possible to forecast weather for 3-6 months in advance, which will have an immediate impact on water resources planning and reducing drought and flood losses.

It should also be recognised that space-monitoring technology is expensive for most of the developing countries. While the computer hardware prices have steadily been going down, software and satellite image acquisition still remain expensive. Further, acquisition time too is unacceptably long for many disaster related research and applications.

6. Geographical Information Systems in Disaster Reduction

6.1 GIS technology in Disaster Reduction

Disaster reduction requires the integration of information from diverse sources. Geographic Information Systems (GIS) is one key new technology often used to collect, store, analyse and display large amount of spatially distributed information layers. The core of a GIS is a set of spatially referenced maps, which are stored either as points, lines, polygons or raster data. GIS makes it easy to assign attributes to these spatial quantities and combine different layers of information.

Natural disasters are the outcome of many complex geophysical characteristics plus the related social circumstances that are subjected to a hazard. The hazards may be meteorological in origin such as cyclones, severe storms, droughts, blizzards or earth processes such as earthquake, volcanic eruptions, tsunamis, etc., or a combination of both as in the case of floods. All these events are location dependent in the sense that a hazard is aggravated by the geological, topographical and land cover at the location of the hazard. Similarly, natural hazards turn into disasters when human societies are affected by them. The degree of damage is dependent on the population density, infrastructure and means for available for mitigation such as flood control dams. In order to grasp the impact of different disasters, it is necessary to understand the interactions and inter-relationships among these diverse and complex characteristics for any given magnitude of the hazardous event. The strength of GIS lies in the ability to represent the real world situation closely with layers of information (maps) that can be combined in a predetermined manner to identify the impacts of a natural hazard through the introduction of hazard dimension as in the case of flood, the water height and the flood duration distribution or ground shaking due to an earthquake.

GIS has developed substantially over the past decade with the advent of large volume data handling capabilities that facilitate synthesising information from many different data sources. It has become an indispensable tool for managing complex information related to both societal and environmental functions. Disaster reduction discipline has benefited largely from these developments in risk map preparation, damage assessment and modelling for forecasting and planning.

This section briefly describes the current status and use of GIS in disaster reduction.

6.2 Hazard Mapping

Identifying the risk from natural disasters is an important requirement for mitigation and preparedness. The automation provided by GIS could be directly used in microzonation, as the basic information fusion process involving comparison, indices and overlaying in microzonation is the same as basic GIS operation. Depending on the type of disaster, there are a varying approach for preparing risk maps. For example, in the case of floods, the possible hazard scenarios are more deterministic than for earthquakes or cyclone disasters. By combining hazard impact for different scenarios at different probabilities, with population and infrastructure, distribution risk maps can be prepared. Another approach is vulnerability analysis, where the hazard potential is considered to be equally distributed regionally. This approach is adopted in earthquake microzonation where each location is subjected to the same type of ground motion and vulnerability is assessed based on the geological structure of each location. In either approach, there are many uncertainties in the assumptions related to hazard scenario as well as in the regional physical characteristics and the forecasting models employed in the hazard estimation. GIS is effective in carrying out such analysis as the automation of the process within GIS as different outcomes resulting from changed input parameters, assumptions and scenarios can be easily carried out.

In the case of flood risk map preparation, first the flood extent estimate is prepared, either from historical data, or through numerical simulation of selected extreme events. If numerical simulation is to be carried out, data other than the meteorological input it is necessary to supply a host of other information related to the locality depending on the type of hydrological and flood plain model used. At a minimum, it is necessary to have the elevation information to determine the surface gradients, and the land cover information to estimate the surface roughness of the catchment together with the physical characteristics of the river. Once the flood extent for a given frequency has been established, the risk can be estimated by overlaying the population distribution and infrastructure information on the inundation map. If several inundation maps are prepared for different flooding probabilities it is possible to

establish the risk of people and assets subjected to flooding. Further, by providing information related to infrastructure, such as fragility curves for buildings, vehicle density on the roads, it is possible to estimate the economic risk on the flooding area, by combining this information with floodwater depth and duration from the inundation maps.

For response, it is necessary to identify passable roads, locations of emergency services, refugee camps, feasible transportation routes and host of other information, which can only be derived by combining most recent disaster status information with other static information, related to the infrastructure.

6.3 Damage Assessment

Damage estimation from a potential hazard is a key parameter in designing mitigation measures. While it is difficult to estimate intangible damage such as injuries, anxiety in a purely deterministic manner, there are GIS systems that are currently available or are being developed to estimate both primary and secondary tangible damage. The methodology widely followed is to establish fragility functions for different types of property, such as residential and non-residential buildings, infrastructure, crops, farms, etc., which express the potential damage as a percentage of cost under a particular type of hazard, given by the depth and duration of water height in case of floods or ground shaking intensity in case of earthquakes. By overlaying the map of hazard level on the property distribution map, the damage estimation can be carried out either in an external model or within the GIS depending on the complexity of fragile functions and damage estimation model.

6.4 Support for Simulation and Modelling

Mathematical simulation and modelling disaster processes is the main procedure in forecasting or warning, as well as in impact assessment. Unfortunately present day GIS cannot handle time varying information or dynamic updates of information required in the modelling of disasters. However GIS is widely used to prepare the input information to

mathematical models as a pre-processor. The ability of GIS to process complex spatial information as inputs has in turn helped to produce more complex models capable of representing the disaster scenarios in more detail.

6.5 GIS in Planning

GIS has become a prominent tool for city and infrastructure planning in general. Operational use of GIS in disaster mitigation are few, but several examples in land management response and reconstruction are reported. In more specific examples, GIS is used in securing lifelines such as gas, water and electricity are used by industry.

GIS based response systems have been successful in the fire-fighting industry, where spread of fires and fire conditions can be generalised and the systems used continuously. During major disasters, the chaos and the rapidly changing situations have prevented the use of GIS in response although many response systems have been developed or are under development. On the other hand, GIS has been heavily used in the recovery process in the aftermath of a disaster. Demolition, relocation and reconstruction have been greatly assisted by GIS technology in the aftermath of Northridge and Kobe earthquakes. GIS has also been used in selecting locations for resettlement after a disaster.

6.6 Overview of GIS Utilisation

GIS technology is helpful in integrating data from various sources in all phases of disaster cycle. Especially GIS information can easily be combined with detailed land cover information obtainable from remote sensing, which can update with changing information. GIS technology is not inexpensive, even though hardware prices has been steadily declining. On the other hand, software as well as training takes up a lot of resources, and before the benefits of GIS becomes available, a considerable investment in time and resources is required in the preparation of data and training.

At the global level

It is important to realize that GIS is only a tool for overlaying maps, and that it makes such overlay and integration easy. The results of GIS processing is determined by the analyses carried out and the quality of data. The most expensive part of the GIS use lies in the data preparation. It is important to note that more and more regional and global data of topography, landcover, soil characteristics, etc., prepared under various international and regional collaborative programs are becoming freely available. This makes it possible to start on GIS programs with base data sets that can be upgraded with more detailed data if the need arises.

At the national level

In preparing data for GIS, it is extremely important that these data, especially the static data that would not change often, are produced as collaborative efforts between various governments and other organisations. Experience shows that unnecessary duplication of this expensive endeavour delays the widespread use of GIS in many countries. It is important for governments to have a national policy on the development and sharing of digital data related to disaster mitigation efforts.

7. Global Positioning Systems in Disaster Reduction

At the global level

The rapid decrease of prices in GPS receivers has made it a useful technology for disaster mitigation. Using a constellation of 24 satellites, GPS receivers estimate the absolute position on any location of earth, provided a sufficient number of satellites are tracked. In the standard positioning service (SPS) freely available for civilian use, horizontal accuracy is around 100 m, where as in the precise positioning service available for US military and authorised users 10-20 m accuracy is obtainable. However, the accuracy can be drastically increased with differential GPS (DGPS) where two receivers are used with one receiver located on a point with known coordinates. In DGPS, the differential GPS accuracy is obtained in real time by having the reference location broadcast the differential correction to the user in real time. Typically 1-5 m accuracy is obtained, and this procedure is used commonly in the transportation industry. A real time kinematic (RTK) system is a real time differential

positioning system, which additionally use phase data. Accuracy of mm to cm order is obtainable with RTK systems. The present day prices of GPS vary from about 150 - 300 US\$ in the SPS market to around 20,000-40,000 US\$ in the RTK receivers.

At the national level

At the national level, GPS arrays are used in the monitoring of earthquake movement (ex. Japan has 1000 node array for monitoring minute ground movements), atmospheric vapour flux which would lead to better representation of climatic parameters in local area climatic models for weather forecasting and volcanic movement monitoring. High precision GPS can be used in the national survey programs to improve the topographic maps and feature attributes used in various maps required in the hazard map preparation.

At the local level

GPS is expected to contribute significantly in the response and relief phase of a disaster, especially when it becomes difficult to locate positions in the chaotic situations that follows a large-scale disaster. GPS use has been tested in relief co-ordination where a large number of relief workers may not be residents of the area to guide relief operations smoothly, for damage estimation and for quick relief and recovery in both infrastructure and lifeline systems.

GPS is also used to enhance the accuracy of existing topographic information by providing a means to acquire additional data rapidly. This is very valuable in preparing flood risk and landslide hazard maps in remote areas where terrain measurements are not adequate.

In the reconstruction phase where topographic features may drastically change and new constructions had to be carried out quickly, rapid and accurate surveying capabilities of GPS are expected to play a major role.

8. Mathematical Modelling in Disaster Reduction

Mathematical modelling plays a key role in hazard assessment, forecasting and warning. Recent advances in acquisition of spatially distributed information through remote sensing,

processing of that information in GIS and the advancement of knowledge of basic disaster mechanism are making it possible to represent the natural phenomena more closer to reality. Most natural processes resulting or leading to disasters involve complex interactions of many processes, which generally require numerical computations. Improvements in computational capacity combined with the rapid growth of computational power, declining costs and continuous advancements of model developments are contributing to the simulation of disaster-causing natural phenomena with increasing accuracy.

There are mainly two categories of numerical modelling activities related to disaster mitigation. One is the simulation of the phenomena itself, that can be used in scenario analysis to identify risk and the other is to forecast the future state of an extreme event currently taking place. Currently mathematical modelling is used operationally in weather forecasting, cyclone tracking and strength prediction, flood forecasting, lava flows resulting from volcanic eruptions, forest fire and management modelling, landslide hazard identification, landslide forecasts, behaviour of structures during disasters, relief operations and tsunami modelling.

At the global level

At global scale numerical modelling is used in long term climatic modelling. The trends resulting from these modelling provides fundamental information for environmental policies to counteract global climatic changes. At regional scale climatic models are operationally used in the weather forecasts. Volcanic ash, forest fire effects are two other areas where regional scale monitoring and modelling are used for detection and warning. Tsunami warnings are another area where successful predictions have been carried out at global and regional scale.

At the national level

At the national and local levels, mathematical models are used in all most all types of disasters. Mathematical models are approximations of the physical reality that involves many simplifications and assumptions with regards to the natural phenomena being simulated as well as the environment being modelled. Proper use of mathematical models depends on the following information used in model setup and verification.

- Information used to represent the physical and social environment (land cover, topography, population distribution, transportation, etc.)
- Data used to represent the physical phenomena (ex. Rainfall in case of floods)
- Data used to calibrate the models
- Data for verification of the models

In this respect, one of the most important requirements of mathematical modelling for forecasting, warning and risk analysis is the historical data of past disasters as well as long term record of magnitude of natural phenomena, even when they do not cause disasters.

At the local level

A fundamental difficulty of using model forecasts at the national level lies in interpretation of results at this, or at human scale. Due to limitation of computational power and data availability, simulations are generally carried out at a scale much coarser than that is applicable in the day to day life. While various nesting techniques are tested to increase the resolution at the vulnerable areas, unlike in the case of static data, computational methods are not versatile enough to arbitrarily change the resolutions in modelling complex interactions related to natural disasters. Therefore it is necessary to develop methods to translate the model forecasts to the appropriate scale and the predictive capability of the models.

9. Communication in Disaster Reduction

9. 1 Role of Communication in Disaster Reduction

Communication is an essential component in all aspects of disaster management, from mitigation, preparedness, response to recovery at global, national and local levels. Communication consists of the message of data being communicated and the media used in the communication. Here only the communication media is discussed, excluding the content of the message, as the content and form of the message is too diverse and community dependent. However, it should be borne in mind that it is the content and format of the information exchanged that determine the successful utilisation of communication in disaster reduction, be it in the data exchange or warning to general public of the impending disaster. The most revolutionary growth of technologies during the IDNDR decade took place in

telecommunication. Fuelled by the enormous possibilities in the use of Internet and the advent of wireless telecommunications we have seen enough increase in interest and opportunities, that it is expected that global communication will have access to further decrease in price with the deployment of big and small Low Earth Orbit (LEO) Satellites and Medium Earth Orbit (MEO) Satellites in the near future. The connectivity offered by these communication media becomes invaluable in the aftermath of a disaster as the dependence on conventional ground based communication media vulnerable to disasters would be lessened.

9.2 Communication Needs

Three forms of communication needs may be identified. In the mitigation phase, exchange of methodologies, historical information, real time as well as past data and computer applications for disaster related modelling, would be primarily exchanged at both global and national levels by engineers and scientists involved in the mitigation planning and detection of disasters. At the national level, the most important issue is to establish communication infrastructure for the data and information exchange among various agencies involved in the disaster mitigation. This is a complex task given that the issues to be dealt are not purely technical but mainly dictated by the degree of coordination achievable among various agencies and individuals involved. The integration required in disaster management makes it necessary to bring together data archives maintained by different organisations developed for specific tasks where the data formats and standards differ. Often it is necessary to re-establish or redesign databases and associated systems due to this exchange difficulty. At the local level, communication needs for mitigation are again for assessing risk for mitigation which require data on the natural and the built environment, communications for learning, sharing experiences and methodologies.

At the preparedness phase, global communication needs are for the operational monitoring and forecasting and exchange of information on practices and lessons learnt, while at national and local level the requirements are for awareness building response strategies, forecasting and warning dissemination. The WMO has the best example of operational global communication network for disaster preparedness under world weather watch program, which operates, at global, regional and national levels. Under world weather watch there are three

subsystems, namely global observing system (GOS) consisting of facilities for observations including satellite receiving stations, radar and ground and airborne observation systems, global telecommunication system (GTS) consisting of a network of telecommunication facilities and global data processing system (GDPS), consisting of world and regional centers for providing processed data and analyses and forecast products.

At the response and recovery, global level communication needs are for international assistance, information coverage, while at national and local level primarily the communication needs are for crisis management, relief and recovery co-ordination and information dissemination.

9.3 Communication Media

Communication media available at various disaster phases

Disaster Phase	Mitigation	Preparedness	Response and recovery
Global	GTS Mobile Satellite Internet	Internet Mobile Satellite	Internet Mobile Satellite
National	Terrestrial telecommunications Internet Local area networks Mass media	Terrestrial telecommunication Mass media Internet VHF radio HF radio Amateur Radio Mass media	Mobile satellite Radio VHF radio HF radio Amateur Radio Mass media
Local	Terrestrial telecommunications Internet Local area networks	Terrestrial telecommunication Mass media Internet VHF radio HF radio Amateur Radio Mass media	Terrestrial telecommunication Mass media Internet VHF radio HF radio Amateur Radio Mass media

Different types of communication media exist from which disaster managers can choose, as listed above. However depending on the affordability, especially in the developing countries systems that are used in practice vary considerably. The cost of INMARSAT mobile satellite is about \$4,000 - \$35,000 for hardware where as HF radio may cost around \$4000 - \$5000 for a range of 2,000 - 3,000 km. These costs, especially related to satellite communications is expected to rapidly go down in prices comparable to those of terrestrial based telecommunications with the deployment of new LEO and MEO satellites within the next 2-5 years.

At present, mobile satellite systems use is limited to international organisations and large NGOs with the exception of a few national systems. SSB HF permits voice communication as well as data transfer at low speeds and is widely used by the disaster managers. VHF radio is commonly used at local level between the field offices and local head quarters.

9.4 Guidelines for Communication in Disaster Reduction

Damage to communication infrastructure is one of the most urgent problems to be solved. Too often large scale disasters especially floods, high winds and earthquakes disrupt not only conventional terrestrial communication systems but also specialised radio networks intended for disaster management. Most response and recovery plans depends heavily on the communication and accurate assessment of disaster situations, hence the disruption to communications can often paralyse response and recovery plans.

With satellite based telecommunications becoming a viable option a gradual shift to such systems where the dependency on land based infrastructure is reduced, should be taken into consideration in future expansion of communication infrastructure for disaster reduction. Redundancy in communication infrastructure for preparedness and response should be planned taking advantage of the declining costs in telecommunications.

9.5 Role of Internet

With the growing realisation that a more comprehensive approach is required in dealing with disaster reduction, communication media adopted in disasters mitigation should make it possible to integrate and communicate different levels of information seamlessly. In this respect the role Internet had been playing in all phases of disaster mitigation is noteworthy. With the explosive growth of the number of computers connected to Internet with the advent of user-friendly web browsers, the World Wide Web (WWW) is living up to the early expectations of computer networks for enabling data exchange and computational capabilities across borders. During the past few years, the WWW has become one of the most important communication media for disaster reduction. Its greatest contribution lies in the mitigation and preparedness phase, where it has now become possible to access basic data at global, regional and national levels required in disaster mitigation. Global and regional scale topographic, land cover data sets are available for download while more dynamic information such as temperature, vegetation cover, etc., are updated and posted in the WWW by various

organisations. Some basic data available at 1 km grid resolution such as topography, soil texture, land cover, etc., are quite sufficient for regional level planning and risk mapping while their accuracy can be upgraded incrementally to suit local application. Similarly, mathematical programs, status of different models and simulation results, such as regional daily numerical weather forecasts are available in the WWW, which can be downloaded by national and local authorities concerned with the disaster management. This direct access to the latest technology should be fully exploited by developing countries to strengthen their disaster reduction capacity. At the preparedness state, in addition to operational regional weather forecasts and cyclone warning, research is underway for forest fire detection, flood forecasting and other disasters. At the response level, the WWW has played a strong role at local, national and global level in disseminating information on affected people and damage conditions as well as to solicit and co-ordinate relief.

10. Disaster Information Systems in Disaster Reduction

10.1 Functions of a Disaster Information System

A disaster information system attempts to follow the complete path of the monitoring and analysis associated with a hazard and to come with the resulting disaster scenario. At different levels of development they may serve as automatic response systems, carrying out specific actions, or damage assessment systems estimating the probable damage from a given hazard or as a decision support tool.

Disaster information systems are key tools for disaster reduction in every phase of the disaster cycle as shown in Figure 2, such as in planning, mitigation, preparedness, rescue, recovery, and reconstruction. It can also be used to deepen understanding of the mechanism of natural hazards and disasters, problem finding, education, etc. Disaster information systems are related to various fields and composed of many technologies; computer, information, communication, Internet, satellite, GIS, GPS, Remote Sensing, database, image processing, monitoring, space and time inter/extrapolation, lifelines, manual, risk management, crisis management, emergency operation, laws, training/drill, recovery, reconstruction, etc. This shows that integration of technologies and knowledge of various fields is needed for disaster

information systems. Accuracy or applicability of the system depends on the device or model whose accuracy is the lowest among all components of the system. Therefore a well-balanced combination of subsystems or tools is essential to implement a proper system.

Important issues related to disaster information systems, especially to "Real-time" systems can be considered as, proper preparedness (hard and soft wares) before the event, efforts to minimise new computations during and after the event by efficient use of time before the event, various simulation with different conditions and database with associated results. Quick collection of disaster information and understanding of changes of needs with time is important.

For disaster information systems at the global and national levels, collection, up to date system and standardisation of disaster related information is important. Using these data, vulnerable areas can be found before a disaster and damage estimation just after the event can be done. In this level, accuracy is not a priority and even relatively rough estimation can be used.

At the local level, additional considerations should be taken into account, reflecting higher resolution of information required to take responses, differences of characteristics of physical infrastructure, demographic considerations and possible actions if the system is to function as a decision support system.

10.2 Status of Some Disaster Information Systems

Several disaster information systems have been developed and many are in the development stage as described beforehand. As an example, some of the disaster information systems in the earthquake field in Japan are described below.

Functionality of some current earthquake DIS in Japan

Assist Understanding	Assessment	Response
Kyoshin Net (NIED)	Disaster Information System (Land Agency)	
	SIGNAL (Tokyo Gas)	
	HERAS Railway Technical Research Institute (RTTI)	UrEDAS (RTTI)
	Kawasaki System	
	Tokyo System	

10.2.1 Kyoshin Net

After the Kobe Earthquake, the National Research Institute for Earth Science and Disaster Prevention (NIED) of the Science and Technology Agency deployed a total of 1,000 strong motion accelerometers throughout Japan. This network is named "Kyoshin Net" or "K-NET" and the average distance between stations is 25 km. Each station has a digital accelerometer having a wide frequency band and wide dynamic range. The maximum acceleration which can be measured is 2.0 g. Instruments are placed on free field. At each site, P and S-wave velocities were measured by downhole PS-logging as well as SPT N-values.

Each instrument has two communication ports. The first one is directly connected to a modem belonging to a municipality. The municipality can use the information for emergency management. The second port is connected to the control center at NIED. After receiving prompt information from the JMA, the control center acquires records using this port. The control center compiles these records and then makes the compiled data set available on the Internet. The center also maintains a strong motion database and site information for scientific studies and engineering applications.

10.2.2 DIS by National Land Agency

New early damage assessment systems are also being planned by a number of public and private organisations. After the Kobe Earthquake, there has been a boom on early damage assessment systems. Hence, it may not be easy to get information on all the systems that have been developed recently or are being planned.

As a typical example of such systems, the National Land Agency, which is in charge of disaster prevention administration in Japan, developed the first version of early damage assessment system and started its operation in April 1996. Using the intensity and source information from the JMA and the GIS data from the entire Japanese network using a 1 km x 1 km square mesh, this system estimates the seismic intensity, the number of collapsed wooden houses, and the number of deaths due to collapse of houses in each mesh. Distribution of tsunami height and flooded area is also estimated by this system. In case of devastating disaster like the Kobe Earthquake, there is a delay in the flow of information on damage to the government. Hence, the result of damage estimation by the new system will be used in the crisis management by the Japanese Government at an early stage. The National Land Agency is now developing a more integrated emergency management system called the Disaster Information System (DIS). The above mentioned damage assessment system will be a part of the integrated system.

10.3 Practical Considerations for DIS

Even with the obvious advantages outlined above, there needs to be a discussion before a disaster of the social expectation and needs of the users as well as the acceptable risk so as to properly utilize DIS:

Issues of current systems are listed below. In many cases, the simulations are carried out using static conditions, where as the time factor is very important, especially, the human related activities. However, this aspect is not treated well enough in the present systems.

Damage to structures is the major output of these systems. As the systems are based on many assumptions, accuracy of estimation becomes low and in effect losing the trust of the users, especially specialists. Also the objectives of the systems are not clear, especially in local government systems. There are also not enough discussion, for example, on how to use the results either with regard to government users, or to people directly. Another important aspect that needs to be considered before implementing DIS is the question of which aspect should be emphasised. Should it be for education, for warning, for preparedness, or for decision making during emergencies?

The application of DIS as to what kind of damage could be reduced such as human casualties, structural damage, city functions, information, business, etc. should also be discussed. The question remains as to what should be protected and which damage should be reduced? In case only certain aspects or a part of these can be protected, then which should be selected? Human casualties due to flood and/or typhoons can be reduced by information systems, however, for earthquakes and based on the Kobe experience, most of the deaths were due to collapse of structures within very short time. It means that most of the deaths due to Kobe earthquake could not be prevented by most high-tech post-quake measures. These realities should be reflected in the information systems.

For strategies for optimum pre-event, during-event and post-event operations, the first step should be the evaluation of existing countermeasures. Secondly given a set of information at a particular time, what is achievable should be considered. Next, based on the above survey, discussion of cooperation/coordination among those concerned with different subject areas should be carried out. For implementation, information collected and results obtained should be open even if it makes a part of the society confused during certain periods of implementation. It is very important to consider the normal daily functions of the system, not only for emergency use. Finally, the scenario generation and planning capabilities of DIS can be used in rebuilding better cities and functionality in the aftermath of a disaster.

11 Disaster Reduction Policy for Technology

11. 1 Specific Measures for Disaster Reduction Policy

All of the five objectives of the IDNDR in 1989 refer to roles of the scientific and technical communities. In order to make use of these technologies, national policy on disaster reduction should take measures to make the technologies available, be functional and effective for disaster reduction with the following specific measures.

- Mobilisation of all ministries and agencies concerned for technology development.
- Establishment of national consensus for disaster reduction policy. The policy should be an important component of the national development plan.
- Establishment of long term and short term objectives in terms of disaster reduction within the national development plan.
- Efficient co-ordination of technologies.
- Adoption of a variety of technologies within the national plan, not necessarily the advanced or sophisticated technologies, and the allocation of responsibility for these technologies appropriately among different ministries and agencies.
- Establishment of an agency for research and development.
- Systematic archiving of disaster experiences.
- Providing information technology tools to disaster reduction communities in terms of technologies and expertise.

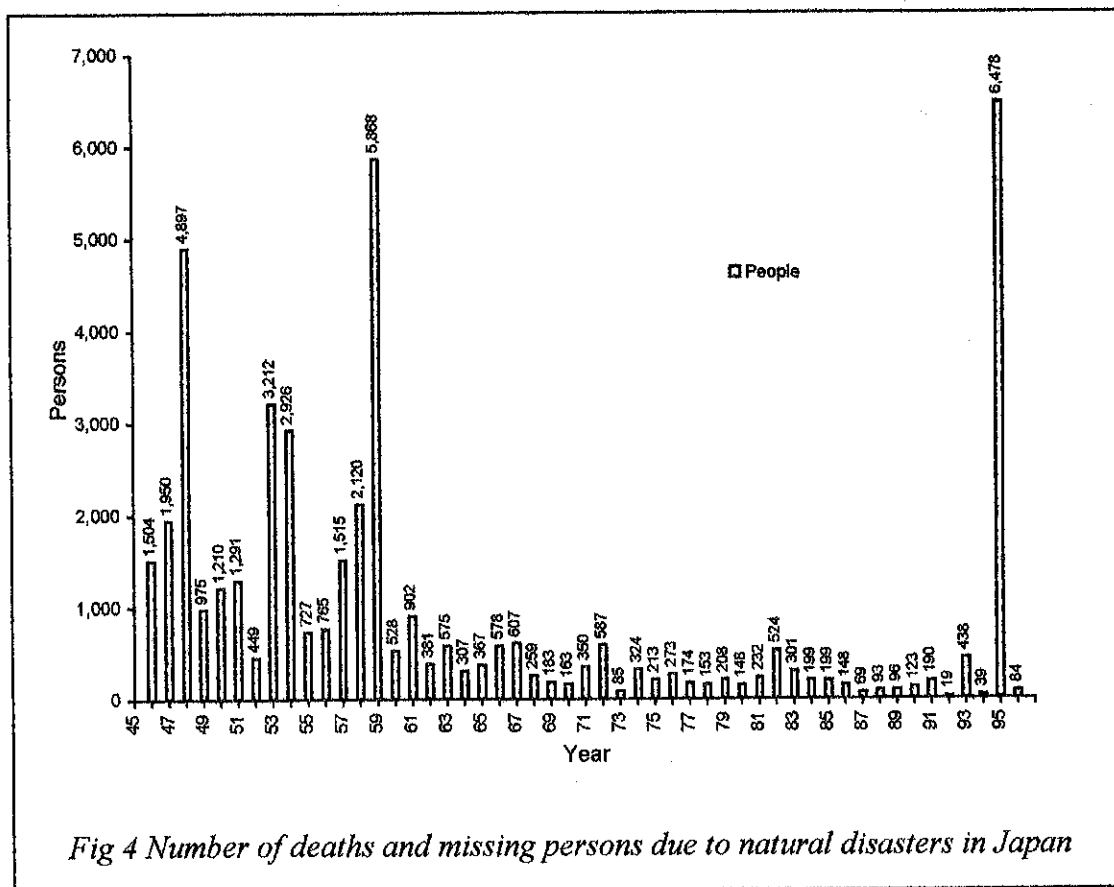
The basic features of the above mentioned measures are discussed in relation to the experience of Japan in disaster countermeasures.

11.2 Japanese Experience

The Japanese experience in disaster counter measures show that government commitment is essential for effective disaster reduction technologies to be functional. From the above mentioned items, it may be deduced that there should be (a) Identification of goals – a national policy (b) Allocation of responsibilities (c) Allocation of funds and (d) Investment for research and development as key components in a national disaster policy.

11.2.1 National Policy

Soon after the war, Japan has suffered heavily from floods, earthquake and typhoons. In 1958, 'Japan enacted that Basic Act for Measures against Natural Disaster', based on which various specific measures were taken against natural disaster reduction. Two basic national laws, "Guarantee of basic living environment for all" and 'Preservation of National Land' were adopted in the counter measures against natural disasters. These principles makes the government obligatory to provide protection against natural disasters to citizens as well as to recover land affected by a disaster to a safe state if the inhabitants of the affected area wish to continue living there. A rapid drop of disaster victims has resulted due to various measures against natural disasters taken under the act. Figure 3 shows the number of dead and missing plotted from 1946 to 1995. The drastic reduction of the number of victims is seen from the figure 4, even though the number again rose after the Kobe earthquake in January 1995.

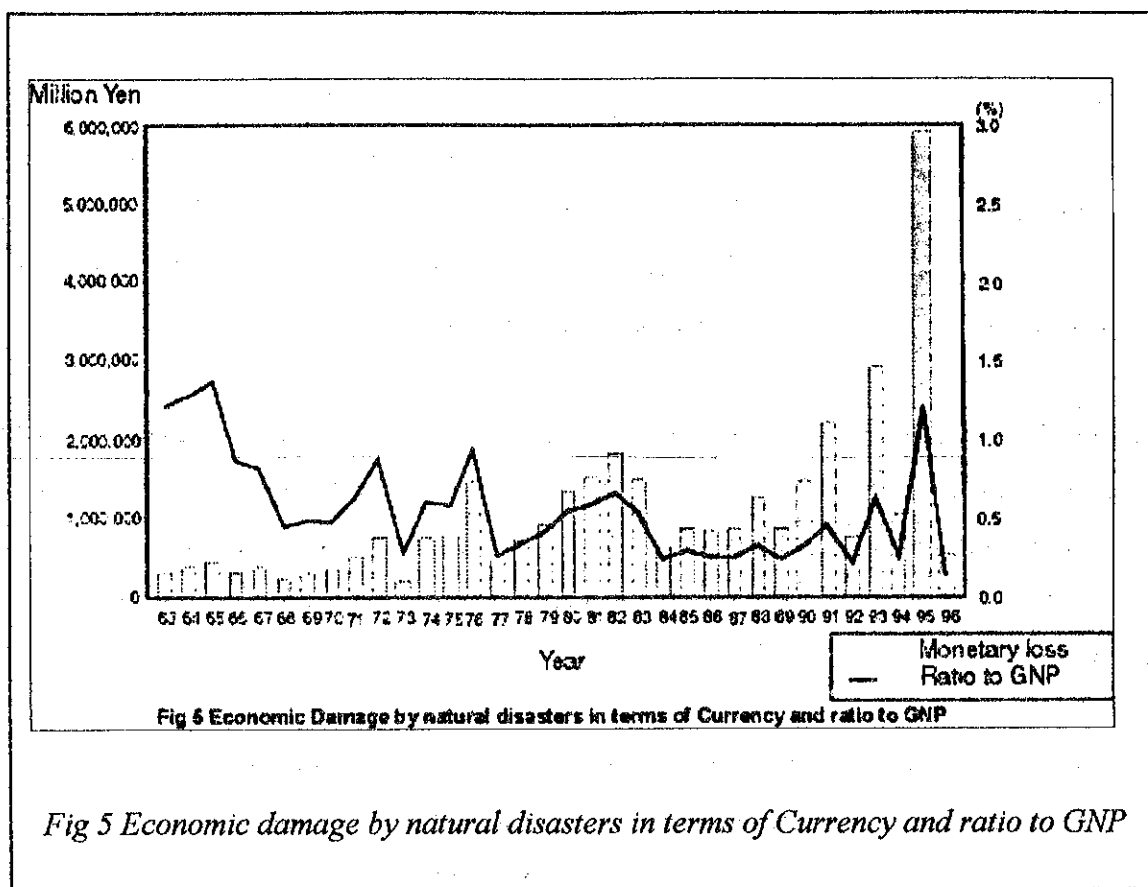


11.2.2 Allocation of Responsibilities

It is rather difficult to allocate responsibility on disasters in an optimal manner. What is needed is to ensure that there is clear-cut responsibility with respect to various aspects of disaster reduction. One option is to install an independent ministerial or departmental level organisation exclusively dealing with disasters (ex, Colombia). However, it may be difficult for such an organisation to function adequately, as long as the activities related to that particular discipline (eg. floods) is the responsibility of a different organisation (eg. public works) when there are no disasters. The other method is to allocate responsibilities to different ministries or organisations where the mitigation activities related to that disaster is closest to that organisation's normal operations. The difficulty in this approach is the lack of co-ordination and identifying grey areas which are not specifically anybody's responsibility. In Japan, the second mode of operation is adopted, where a co-ordinating body, the National Land Agency, has been formed to co-ordinate as well as identify disaster reduction strategies. This measure also does not function well sometimes due to budgetary and resources limitations of the co-ordinating body.

11.2.3 Government Expenditure

The Japanese government has invested an enormous amount of money for natural disaster mitigation and prevention after the end of the World War II. The amount has been kept above



5% of the national budget (~ 0.8% GNP) starting from a high of about 8% of the national budget in 1960's gradually decreasing to reach around 7 trillion yen in 1995. Figure 5 shows this expenditure pattern. The local peaks are related to specific disaster events such as Usu volcano in 1972, efforts to forecast Tokai earthquake in 1978, Unzen volcano in 1992 and Kobe earthquake in 1995.

There are no general guidelines on how much a country should spend on disaster reduction. According to numbers shown in figure 4, the Japanese government has spent 8% - 5% of the national budget on disaster mitigation related activities. However, a very large part of the government budget has been allocated to large-scale construction works such as dams, roads, etc. The approval for the expenditure had been frequently sought as necessary expenditure for disaster mitigation. However, these activities were also a part of the development process and

often served as economic stimulus for the local community and the construction industry. The effect of this practice is now being critically examined.

11.2.4 Commitment to Research and Development

The Japanese government has strongly emphasised research and technology development related to disaster mitigation. Table 1 describes the budget allocation by the Government on disaster in fiscal year 1997. Out of the total 3,837 billion of total budget, 55 billion yen is allocated for the Research and development. Needless to say, it is largely due to the concerns from the devastating disaster of the Kobe earthquake of 1995.

After the Kobe Earthquake, the Japanese Government enacted another law 'Special Act for Counter Measure to Earthquake Disaster'. This Act forced the Central Government to grant local governments the responsibility to strengthen indigenous prevention measures such as survey of potential of earthquake generating geological faults, which are distributed every where in Japan.

Table 1 Disaster related Budget for Fiscal Year 1997 (in Million Yen)

Item	Budget	Governmental Investment	Total
R&D	54,819	54,819	
Prevention	1,077,710	301,466	1,379,176
Land Use	1,952,161	1,952,161	
Recovery	385,423	65,600	4 51,023
Total	3,470,113	367,066	3,837,179

12 Practical Guidelines for Technologies

Throughout the report, guidelines for practical applications have been given. Here some of the common guidelines relevant to technologies discussed in the report, are noted.

- 1 Technologies should be made usable within the national policy framework

It is important to provide a framework for technologies to be useful both at the national and local levels. For example, hazard-maps or risk-maps should have a way to be disseminated and used by the community for which it is developed. This has to be achieved through local governments as part of its legislation.

Secondly, technologies should be available to communities. When it is not practical or feasible to have the technical capability locally, there should be other avenues available for obtaining the required disaster mitigation related products or services. A case study documents an example in Mindoro, Philippines, where the community had enlisted the services of a consultant to prepare a hazard map for use in development planning. Such services should be encouraged to enable wide usage and acceptance of products of technology.

2 Avoiding duplication through proper co-ordination

Duplication of technology is unavoidable and is conducive for the progress of the technology. However, the base data required for the disaster reduction, related to the physical and social environment is common to all applications and duplication only lead to confusion and waste of resources. Here it is important to carry out proper co-ordination to ensure duplication is avoided and data and information are updated under the government authorisation

3 Standardisation of information

Standardisation of information is required for inter-operability associated with multi-dimensionality of natural disaster reduction. As products generated by one institution can become input information for many other organisations it becomes necessary to have a common standards in information systems.

4. Accessibility of information

Accessibility to information is a pre-requisite to assess the risk and plan counter measures by various organisations. Every effort must be made to make this basic required information available to the general population. The technologies and formulation of methodologies for disaster counter measures development should be encouraged both in the research community and in the industry. In order to achieve this, it is necessary to

make it obligatory for the agencies concerned with the observation of basic data to make it available to the general public. The US has taken the lead in making such information easily accessible for the research community and the public. Japan has been slow to implement data accessibility that resulted in duplication and wastage of resources and time, stifling the development of technology as a result.

13. Research Needs for the Future

13.1 New Approaches for Integration and Response – Disaster Information Systems

13.1.1 Disaster information system as a process for improving preparedness and mitigation capabilities

In this document, disaster information systems have been identified as a future key technology. A disaster information system strives to bring different technologies together in order to assess the impact of disasters on society and search for effective counter measures. This process forces the identification of weak links in the monitoring, analysis and counter measure systems. It will also force the harnessing of rapid information gathering techniques and dissemination techniques to be adopted in the disaster mitigation community.

13.1.2 Disaster information system as a decision support tool

With the availability of the present generation of disaster information systems, which either performs a single task or carry out damage assessment, the next step leads to evaluating response actions. In the complex situations arising from disaster situations, it would be impossible to develop systems to propose appropriate actions, other than for some predefined activities. What should be targeted is to develop decision support tools to generate various scenarios in real time to evaluate effectiveness of the measures. Some examples are the dynamic changes to a flooding situation downstream due to upstream protection, or the order in which lifeline restoration needs to be carried out to ensure the necessary level of recovery of a city after an earthquake.

13.2 Harnessing Emerging Technologies for Disaster Reduction

13.2.1 Utilisation of Internet for disaster reduction

The Internet has the capability not only to facilitate resource sharing but also in assisting capacity building in disaster mitigation. Online systems may be developed as educational tools on the use of mathematical models for prediction and simulation, use of information technology, etc. Further interactive systems enabling development of forecasting systems with resources centres would help rapid sharing of technology especially in developing countries.

Rapid growth of Internet related business has produced many new technologies, among which interface to databases is one important development that should be utilised in disaster management community for the exchange and standardisation of existing data archives.

13.2.1 Improvements to GIS for disaster reduction

GIS is designed to store and manipulate spatial data sets and process attributes attached to different spatial structures. In disaster response it is often necessary to consider information that changes with time and assess the impacts. Research is required to incorporate time dimension in GIS as well as on utilisation of current research in this direction.

13.3 Disaster Loss Estimation Methodologies

Disaster impacts on the economy and development is an urgent task to secure funding for disaster mitigation activities. The present loss estimation methodologies adopted vary from country to country and are at best deals with a subset of the total disaster impacts. Research on generic methodologies for comprehensive loss estimation due to natural disasters on society, business, infrastructure, environment and the development process due to various types of disasters is required. Such generic methodologies should utilise spatial information

related to the distribution of property, infrastructure, agriculture, infrastructure, etc., making it possible to apply such methodologies anywhere in the world.

13.4 Technology to Increase Awareness

Disasters are low frequency events, which one may experience only once or twice in a lifetime. It is important to provide as many opportunities as possible for the general public to experience disaster scenarios in order to build awareness. Research on such disaster environment simulators employing virtual reality, mathematical simulation, etc., should be carried out.

13.5 Sustainability of Disaster Mitigation Technology

13.5.1 Applications of disaster reduction technologies for disaster-free periods

For the sustainability of disaster mitigation technologies they should find application during disaster free periods. Such applications could be found most likely in sustainable development and environmental management. In addition, the resource centres associated with disaster mitigation can act as training centres in their respective disciplines.

13.5.2 Application of disaster management experience in other fields

Disaster mitigation and response require operations under extreme conditions. The technologies developed to manage these crisis situations and the operational experience can be used to manage normal social functions more efficiently, for example in traffic control, city planning, etc. Such possibilities should be explored so that society can benefit from these technologies.

14. Recommendations

14.1 Making Technology Available for All Concerned

One of the main objectives of the IDNDR had been to make existing technologies accessible to most people in the world, especially those who are in need of it. In this rapidly globalizing information age, it is important that all communities keep up with the developments taking place elsewhere in disaster mitigation technology and benefit from it. The United Nations should continue to play this important role by providing access to disaster mitigation technology developments to the global community through dissemination, training and symposia as well as promoting international assistance on technology transfer.

14.2 Disaster Management Should be Encouraged as An Educational Discipline

Disaster management is an important discipline requiring various skills and knowledge on physical processes, engineering, science and social sciences. This multi-disciplinary training is not offered in the present day mainstream educational curriculum. The United Nations should promote the disaster management field as a university degree level discipline.

14.3 Capacity Building for Disaster Mitigation Technologies

Disaster mitigation requires mastering complex technologies as well as emerging technologies. The United Nations should continue capacity building at both institutional and individual level to help developing countries to cope better in reducing natural disaster losses.

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