INFORMATION-BASED PREPAREDNESS FOR EMERGENCY RESPONSE TO LARG-SCALE EARTHQUAKE IN TAIWAN

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KEY WORDS: Large-scale Earthquake, Emergency Response, Emergency Preparedness, Decision Support System, Mapping

ABSTRACT: Taiwan is located in the high seismic risk region. According to the past history, every three decades on average, one destructive would possibly hit and cause severe casualties and huge damages. Beside improvement of seismic design codes, the approaches for upgrading efficiency of emergency response are also essential to save more lives and accelerate emergency relief. In last few years, a project designed to identify required information such like dynamic distribution of population, critical infrastructures, locations of shelters and areas possibly hard hit by earthquake is gradually applied through GIS-based decision support system. From the recent practices of Japan's quake, the Emergency Mapping Team led by Disaster Prevention Research Institute, Kyoto University did yield the great contribution to decision making during most difficult time. In this paper, it describes the fundamental considerations and development for information-based preparedness in Taiwan. Especially, how the information flow combines with earthquake intensity, demographic density, buildings and roads shown on GIS system for bring more comprehensive situation to the commander in emergency operation center. Based on the GIS mapping layers, the suggested actions are also provided to assist allocation of search and rescue teams, emergency relief materials and identification of hotspots of affected areas. Among those required data, the estimation of dynamic distribution of population is the most challenging one. Compared with hydro-meteorological disasters, in most of cases, the population distribution during typhoons is stationary in accordance with dwelling status. In order to have more reliable data of demography, the number of registered users of mobile phone will be a good basis to estimate the population distribution. Within the conclusion, the paper pinpoints the direction of needs to improve information-based preparedness for large-scale earthquake.

1. Risk, Threats, Challenges and Demands in Connection to Earthquakes in Taiwan

Closely looking at the potential seismic risks in Taiwan, seismicity, tools for evaluation, social-economic considerations and new types of risk will be briefly introduced in this section to provide a comprehensive understanding.

1.1 Review of Active Seismicity in the Past and Recent

Taiwan is located on the Circum-Pacific Earthquake belt, and the return period of one destructive earthquake might be expected every ten years on average. The Chi-Chi Earthquake (ML=7.3) that took place on September 21, 1999 was the particularly ravaging one. As a result, the central part of Taiwan was the most hard-hit area with sever casualties and tremendous property losses. According to the statistics data, the overall death toll climbed to 2,490, and 11,300 residents were reported severely injured. The damages of buildings included 51,753 total collapses and 54,406 partial collapses. Based on the report proposed by the Accounting and Statistics, Executive Yuan, ROC, in February, 2000, the estimated direct economic loss of the Chi-Chi Earthquake approximately reached $10.7 billion dollars. Since 1999, no large-scale destructive earthquake ever happens, but there are several cases of quakes with casualties and damages in limited areas. Such as the earthquake happened on March, 31, 2002 that brought down the crane operating at top, 800 meters high, of the Taipei 101 and killed five. Another noticing case took place on December, 26, 2006, though very light casualty and loss on land had been reported, but the large dislocation of the seabed pulled the optic-fiber cables apart that caused a widespread inter-continental interruptions of telecommunications. The United Nations International Strategy for Disaster Reduction (UNISDR) declares the unprecedented type of damage which reminds the industry of telecommunication of strengthening the seismic capacity of the undersea communications cables. From the abovementioned, it clearly identifies the diversity and complexity of impacts brought by earthquakes as the society moves toward a capital-intensive and information-connected one.

1.2 Emerging Threats and Challenges in Consideration of Future Earthquakes

To review and evaluate the potential seismic risk in Taiwan, the earthquake loss estimation system is an important tool for risk identification especially. Taiwan Earthquake Loss Estimation System (TELES), similar to HazUS, was then developed for this purpose. The TELES plays a substantial at planning stage for the regional plan for seismic mitigation (Yeh, 2003;Yeh, 2004). However with factors like the dynamic development of economy, rapid increase of aged and aging population and fast pace of urbanization, more new types of potential vulnerability generally appear and continuously test the preparedness for earthquakes. In economic considerations, the direct losses caused by quakes are the primary targets to be reduced. Therefore, a series of revisions of design codes have been carried out and enforced to ensure the seismic capacity of buildings, bridges, hospitals, infrastructures and etc. However, observations and learnings from the recent earthquakes in New Zealand and Japan, the painful experiences frankly tell the importance to keep the critical infrastructures operate even after strike of large-scale earthquakes. The scope of the critical infrastructures ranges from lifeline systems, power plants, fire and police stations, high-tech industry parks, cultural heritages, schools, financial systems, telecommunications and etc., which sever the fundamental functions to support continuity at national level. Therefore, scanning weak points of the critical infrastructures is a curtail step for seismic retrofit in modern society.

In the aspect of structural change of population, “Aging Society” is the unavoidable factor as designing the measures to accommodate the gradual change, but at fast pace. Compared with major developed countries, the “aging” speed of Taiwan is the second fast worldwide. The challenges need information including the seismic exposure of nursing homes and adequate facilities to help the elders during emergency. Urbanization is an unstoppable trend around the world, as more people are hiving in the metropolitan area that means the highly-populated density heavily creates demands on disaster risk reduction and emergency response. Frist challenge, unlike the emergency operation during hydro-meteorological disasters that most people choose to stay at homes, no precise model is able to forecast the population distribution as the quake strikes.

1.3 Enhancement of Emergency Operation during Earthquakes

In Taiwan, the top two natural disasters are typhoons and earthquakes. On average, about four to five typhoons that occurred in the western North Pacific affect the island every year, bringing destructive winds and heavy rainfall. The economic loss every year due to typhoons could be up to 20 billion NT dollars. The growing commercial activities and development of land use in recent years further increase the potential of flooding and debris flow caused by heavy rainfall. The central government of Taiwan has invested vast resources in recent years to improve the entire system of warning and operational response both in the technical and organizational aspects. Therefore, how to transfer the successful model into emergency operation for earthquakes will need special care to examine the common requests and unique difference. In common, the GIS-based information systems are the tools to enhance the situation awareness by dynamic display the current situations. However, usually there is sufficient lead time to carry out the preparation before typhoons make landfall through assistance of numerical models, but it is impossible to predict where and when to have a major quake. In this regards, some information-based preparedness is required in advance to ensure the smooth and efficient emergency operation. Especially, scenario-based plans require reasonable inputs and parameters to simulate the consequences of earthquakes. To speed up operation of emergency response, a clear GIS-based and near-real-time map of population distribution will effectively help commanders in the Emergency Operation Center make decisive decisions to save more lives. In this regards, some new ideas have been proposed to meet the demands, (Lui, 2010).

2. Emerging Needs Related to Information-Based Preparedness

In reviews of the past quakes, especially the large-scale ones, the extensive damages in the residential buildings could lead to mass casualties and cause problems of inhabitation. And the interruption and destruction of lifeline systems such like telecommunications, power supply and transportation would totally or partially cut off the channels of information transmission that is the general difficulties to be solved at initial stage after large-scale earthquakes. The rising demands of marking up the scopes of affected areas and improving the situation awareness of impacts are the top priorities to achieve in response to major quakes, (Ker, 201).

2.1 Basic Approaches to Produce GIS-Based Information

To evaluate the impacts by major quakes, it requires geo-spatial information to interpret the interactions and interconnections among the affected areas. As trying to provide a comprehensive view of overall situations, three approaches are applied to sketch the geo-spatial distribution on the GIS-based system. Among them, the point location will help to identify the affected buildings, utilities or infrastructures; the line connection will show the degree of interruption of transportation and telecommunications which is essential to assess how to conduct search & rescue and execute emergency relief; the area distribution will illustrate the possible exposure of strained population and damaged structured that help to estimate the demands of post-disaster recovery.

2.2 Practical Examples of Japan after the Tohoku Earthquake, March, 2011

Taking example from Japan right after the great Tohoku Earthquake March 11th, 2011, though the widely-spreading interruptions of telecommunications and transportation severely blocked information transmission from the affected areas which led to difficulties of information collection and integration for facilitating emergency response and relief, scholars of Kyoto University immediately proposed and delivered the operation and mechanism of "Emergency Mapping Team (EMT)" to integrate information yielded by public and private sectors and produce GIS-based maps for accelerating decision making and operations through central to local governments. Furthermore, the EMT also recruited scholars and experts in the local affected areas working together on the maps by cloud technology and disseminate the maps on the Internet for broader application, Figure 1.

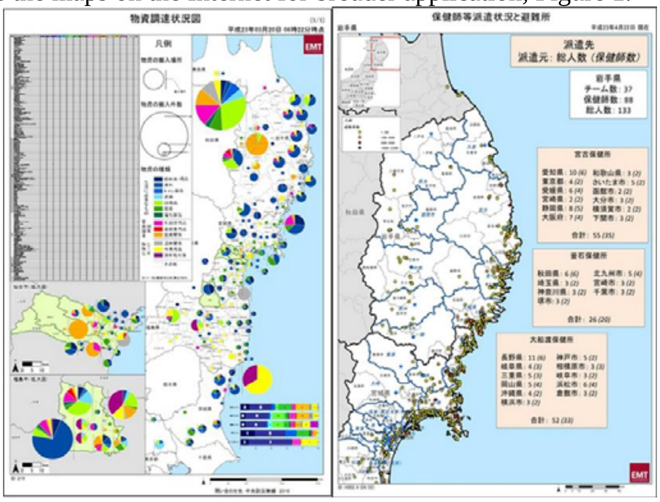

Figure 1. maps produced by the Emergency Mapping Team (http://www.drs.dpri.kyoto-u.ac.jp/emt/maps/)

2.2 Basic Element to Produce Scenario-Based Maps

Since 2010, the National Science and Technology Center for Disaster Reduction (NCDR) has been collecting and digitalizing relevant data including population distribution, highways, critical infrastructures, land use and etc., which would be applied for emergency operation after major earthquakes in regard to the characteristics of possible impacts. Beside direct impacts like building collapse, interrupted bridges, ruined facilities and etc. , it also needs additional attention to liquefaction, landside, tsunami and post-quake fires which are likely sources leading to great losses and casualties. In order to accommodate the abovementioned and produce maps in short period of time, the formats of essential topic maps could be well prepared in advance, Figure 2.

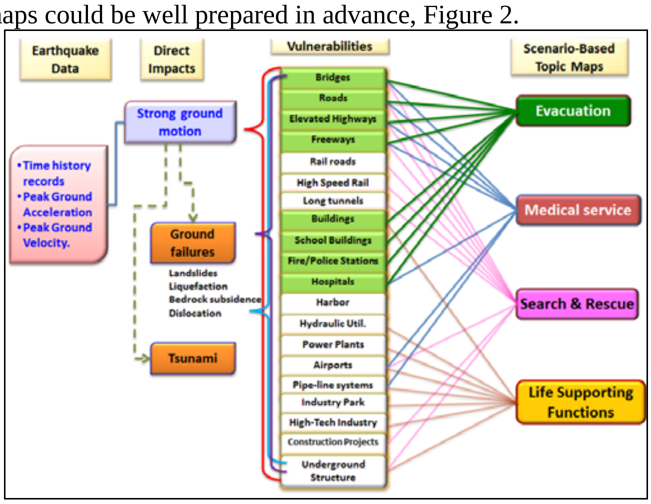

Figure 2 the basic considerations to produce scenario-based topic maps

3. Digitalized and Meshed Grid Data for GIS-Based Mapping

In preparation for mapping process after major earthquakes, several possible scenarios should be included to cope with huge demands found in the affected areas. The commanders in Emergency Operation Center are always eager to knowing the locations and distributions of strained people and damaged areas, and the difficulties and obstacles for emergency operation. With digitalized and meshed grid data ready prior to disasters, the automatic process will be able to produce the maps fitting the urgent demands during emergency. At the initial phase of information-based preparedness, NCDR with assistance of government agencies has completed digitalized data including geological condition, population distribution, critical infrastructures, near real-time intensity maps and warnings which have been applied to drills and real cases already.

3.1 Digitalized Population Distribution

In comparison with the hydro-meteorological disasters as typhoons and flood, even with the most advanced models, there is no any methodology to yield precise prediction of where and when earthquake will happen. It is a challenging job to identify the number and scope of affected people at the very first moment of earthquake. On contrast, most people usually receive weather forecasts through multiple channels and choose stay indoors to reduce life casualties. In this case, the distribution of population, like right before landfall of typhoon, is rather stationary and number of resident by households is easily to get from the annual census data. The stationary demographic data is also valid for the case if the quakes happen at night as most of people are taking rest at homes. In order to catch the dynamic characteristics of population distribution amid earthquakes, especially at day time, the first approach is the proportioned population distribution. By simulating population distribution according to the proportional ratios of base floor area of individual buildings, the proportioned population distribution will roughly illustrate the quasi-dynamic relationship between population distribution and mobility of people, Figure 3. Another under developing approach is to plot a dynamic population distribution based on the number of registered users of mobile phone. Especially during the office hours, it will help to collect where people densely gather together. Furthermore, if collapsed buildings found, the data will provide the significant assistance to locate the possible people under rubble. Within the effective cover radius and locating function of mobile phone relay stations, if with assistance of mobile phone service providers, the data will be the reference for emergency relief and serve as electronic tags of the displaced people. The daily updated and dynamic data will assist both public and private sectors to deliver their aids meeting the demands. After Haiti Earthquake, the dynamic monitoring project on population does help the emergency relief and long-term recover.

3.2 Digitalized Grid Data to Estimate Risk Potential of Landslide

Close to 70% of the whole Taiwan Island is in slope land and dwelling, in order to accommodate 23 million people, cultivation and development are unavoidable along hillside or in mountainous areas. Some of them are highly vulnerable, where tends to have landslide or slope failure induced by the strong ground shakings. If landslide or slope failure happened, the direct impact will be the interruption of transportation which will make communities isolated, especially indigenous tribes. To conduct a quick scan of possibly affected areas after quakes, based on criteria of peak ground acceleration and geological conditions, high risk areas could be identified and displayed on GIS map for executing aerial surveys to verify the situation and carry necessary operations, Figure 4. (Lin,2008; Lin, 2009)

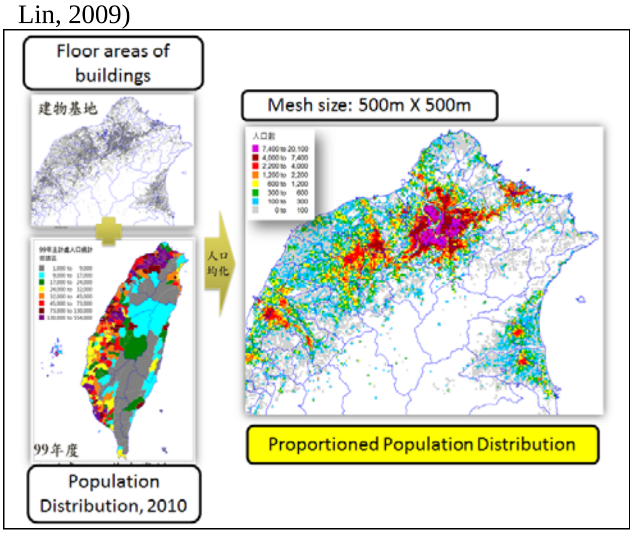

Fig.3 quasi-dynamic population distribution

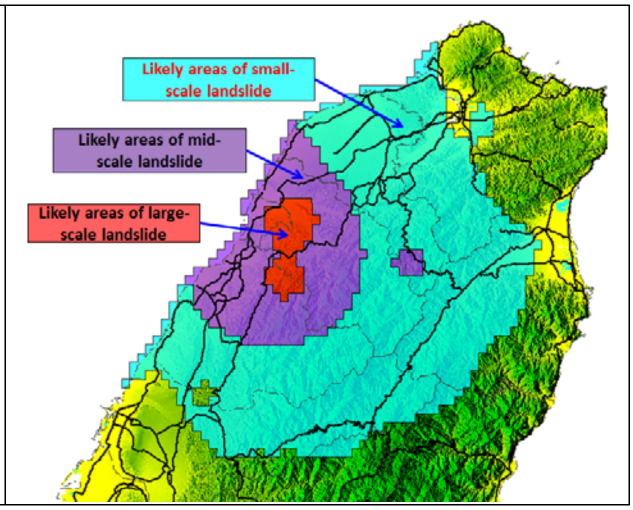

Fig.4 landslide potential map

3.3 Digital Map Layers of Critical Infrastructures

In order to maintain continuity operations of governments, business sectors and public services, function checks on lifeline systems and critical infrastructures are required steps to ensure safe and stable basis for giving confidence domestically and internationally. For example, considering economic contribution, the high-tech science parks are the primary targets of check-list. In 1999, the Chi-Chi Earthquake, the quick recovery of water and power supply did stabilize the global supply chain of electronics. Based on the past practices and vulnerability of infrastructures, the overlapping of peak ground acceleration and locations of critical infrastructures will provide a basic guide for the commander in the emergency operation center to collect related reports or carry our quick survey.

3.4 Automatically Generating Intensity Map Based on Peak Ground Acceleration (PGA)

The intensity map of PAG is one of most important data after major quakes, others like time history record and frequency content of earthquakes, which will help to screen out the possibly hard-hit areas within few minutes after quakes strike. Based on the real-time data shared by the Central Weather Bureau (CWB), the NCDR has developed an application to generate the layer of intensity maps which usually takes less than three minutes after receiving data from the CWB. Due to the scattering locations of real-time accelerometers operated by the CWB, the grid size is 2.5 by 2.5 kilometers, rather than 500 by 500 meters in other meshed data, Figure 5 and Figure 6. In the following, NCDR will also design additional apps to yield velocity maps and response spectrums to assist in precisely identifying the possibly affected areas.

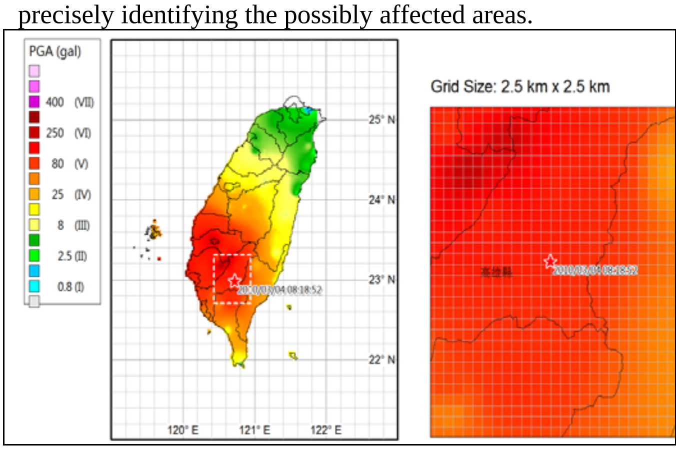

Figure 5 intensity map in 2.5 by 2.5 km mesh format

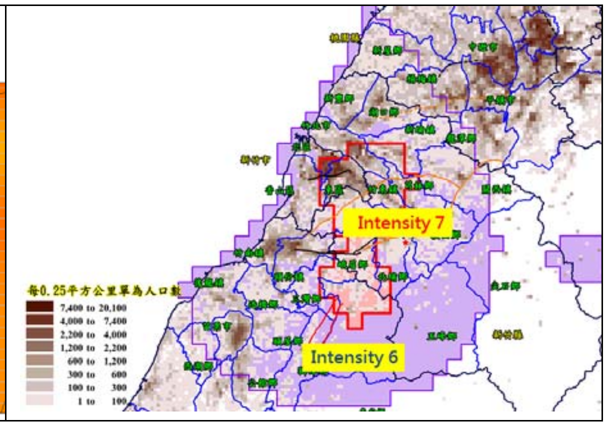

Figure 6 overlapping intensity map with proportioned population layer

4. Conclusions

After drills and limited practical cases, the GIS-base maps did provide clearer and more comprehensive distribution of situations and has received positive response from the emergency operators and responders. Amid the discussion of future development, the following points should be taken into consideration: (Ker,2011)

1. More models should be introduced in the system. Currently, the PGA intensity map provides a sketchy idea of possibly affected areas and damaged structures. It will be welcome if models of vulnerability assessment will be added into the system to generate more detailed warning zones. Modeling plus mapping will serve the valuable tools to double the contribution conveyed GIS systems.
2. Design of follow-up actions and responses will help the emergency responders to carry out the Standard Operation Procedure. Therefore, well developing scenarios is to illustrate the most likely
3. Strengthening the concept of information-based preparedness and mechanism of information sharing is required, especially during routine operation.

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