The Application of Taiwan Earthquake Impact Research and Information Application Platform for Lifeline Systems

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ABSTRACT

In last decade, several large-scale earthquakes have struck major population areas and caused heavy casualties and losses in many countries. Therefore, to understand the impact and disaster scenarios of assumed large-scale earthquakes to urban areas becomes an urgent and crucial task to the central and local governments of Taiwan. The purpose of this research is to develop an integrated research and application platform, Taiwan Earthquake Impact Research and Information Application (TERIA), which is established to evaluate the impact scenario of earthquakes to the metropolitans in Taiwan. Using TERIA platform in this study, the post-earthquake scenario analysis focused on power and water system as examples. Incorporated with geographic information system (GIS) analysis in 500m×500m grids, the characters of ground shaking and liquefaction for whole area are provided. To conclude with it, the objective of this unique platform is to furnish a comprehensive impact and damage scenario to fulfill the necessary data for planning disaster mitigation strategies and preparedness actions that make the cities in Taiwan more resilient to earthquakes.

Keywords：Earthquake, Impact Scenario, Lifelines, Seismic Response

INTRODUCTION

In last decade, several large-scale earthquakes have struck major population areas and caused heavy casualties and losses in many countries. These natural disasters also revealed the vulnerability of communities, buildings, lifelines, communication and other critical infrastructures, which induced cascading impact and catastrophe unexpectedly. As lessons learnt from these great calamities, to have efficient mitigation strategies and action plans in advance is very important. Therefore, to understand the impact and disaster scenarios of assumed large-scale earthquakes to urban areas becomes an urgent and crucial task to the central and local governments of Taiwan.

Figure 1. TERIA platform (Taiwan Earthquake Impact Research and Information Application)

As an independent administrative institution assigned to bridge research techniques and government information for disaster risk management, National Science and Technology Center for Disaster Reduction (NCDR) has established an integrated framework for earthquake impact scenario assessment and application, named TERIA (Taiwan Earthquake Impact Research and Information Application) platform as shown in Figure 1. A demonstrative exercise via TERIA platform was conducted to assess the impact scenarios of a presumed earthquake M7.0 in Hualien city induced by Milun Fault, which is the drill scenario for National Disaster Prevention Day of Taiwan in 2014. Incorporated with geographic information system (GIS) analysis in 500m×500m grids, the characters of ground shaking and liquefaction for whole urban area were illustrated. The post-quake scenario analysis included building damage, causalities, bridges, roadway system, lifelines, and the emergency relief and response systems…etc. Additionally, the established database and comprehensive assessment scenario can be

adopted as a reference for future compound-disaster studies, strategy making, and government policy enactment.

DISASTER RISK MANAGEMENT PROCESS OF EARTHQUAKE

At the boundary of active convergence between the Eurasian and Philippine Sea plates, Taiwan is under intensive threats from earthquakes. Research results have shown the probability of large scale earthquakes in the next fifty years are very high [1]. In 1999, the M7.3 Chi-Chi earthquake occurred at central Taiwan and took away 2,415 lives. More than 11,000 people were wounded, and over 100,000 buildings were completely destroyed or severely damaged. Due to serious damages of infrastructure and lifelines, the performance of emergency response, rescue and relief actions was significantly obstructed. On the other hand, the electronic power system was interrupted, and it caused alternative power outage for more than two weeks in most northern region of Taiwan. The fails of power supply initiated huge business impact to many industries, including the world's largest electronic OEM companies in Hsinchu Science Park and other industrial zones. The direct economic loss due to power outage is about 2 billion USD [2], and the total economic loss caused by this earthquake is 12 billion NTD [3]. As lessons learnt from Chi-Chi earthquake, governmental agencies have supported numerous research work and implemented several important strategies on disaster prevention of urban earthquake.

Figure 2. Risk management process on earthquake impact [4]

The process of risk management on earthquake impact is typically expressed into few steps: hazard identification, inventory collection, direct and indirect impact assessment, restoration and mitigation, and evaluation and revising (Figure 2). To implement the process needs interdisciplinary cooperation from geology, earth science and earthquake engineering to identify the probability of earthquake hazard; an comprehensive inventory data collected from governmental and private sectors;

impartial models to assess the direct and indirect impact scenarios; and the implementation of mitigation strategies supported by governments and communities. According to the result of comprehensive scenario investigations and assessments on the assumed large-scale earthquake, the countermeasures and acts on disaster risk reduction are then effectively legislated. In Japan, several disaster-prevention countermeasures have been enacted: the Large-Scale Earthquake Countermeasures Act (LECA), The Earthquake Countermeasures for the East (Japan) Sea, Southern East Japan Sea, and South Japan Sea, and the Earthquake Countermeasures in the Capital Regions [5]. The United States has also promoted the Public Building Safety Act and California Earthquake Hazard Reduction Program [6].

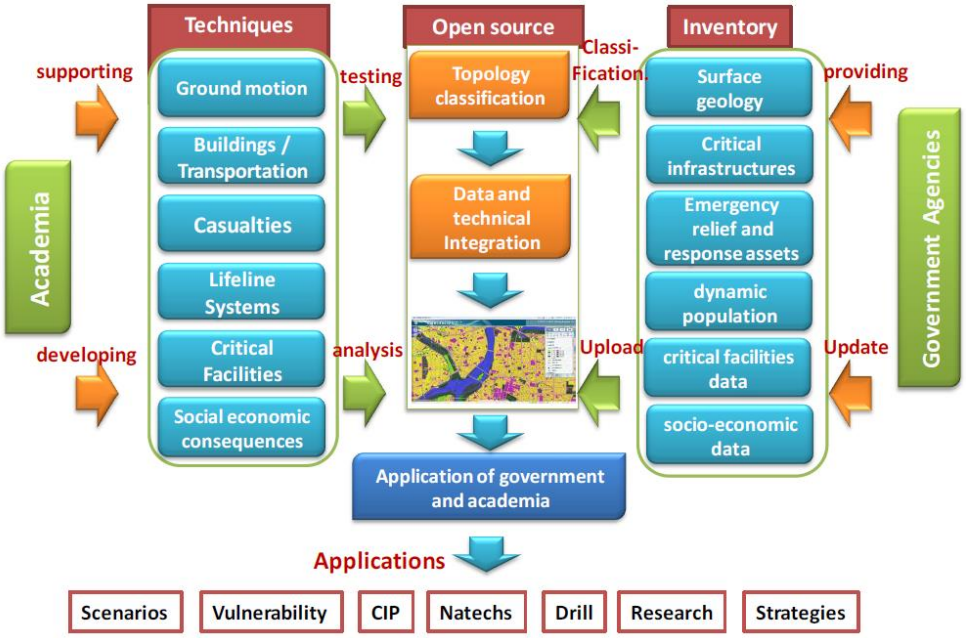


Figure 3. The framework of TERIA platform.

As an independent administrative institution supervised under Ministry of Science and Technology (MOST), NCDR is assigned to integrate scientific knowledge and techniques with government resources, and provides the results to assist strategy and policy making. To aim to this objective, NCDR establishes a platform "TERIA" to incorporate diverse techniques and data for earthquake impact research, and apply the results and information for disaster mitigation and prevention. The stakeholders of TERIA platform include research institutes, private sectors, local government and central government. The development of TERIA platform is purpose-driven, and it is prepared for the national-level drill and preparedness. Its main applications are to support academic research, to enhance assessment models, to study and review the comprehensive earthquake impact scenario, and to apply integrated information and

data for the tasks on disaster mitigation and prevention. Figure 3 illustrates the framework of TERIA platform and its applications. As an open-source interface, all the inventory data are protected and expressed in 500m × 500m geospatial grids.

SEISMIC SCENARIOS – SITE SPECIFIC

To demonstrate the operation mechanism of TERIA platform in an early stage, the direct impact scenarios of a presumed M7.0 earthquake in the Hualien city induced by Milun Fault are evaluated. In each 500m × 500m geospatial grid, the distributions of peak ground acceleration, peak ground velocity, and permanent displacement are simulated. The earthquake hazard scenario has included site specific analysis of ground motion. The result of the seismic hazard analysis is graphically shown in Figure 4.

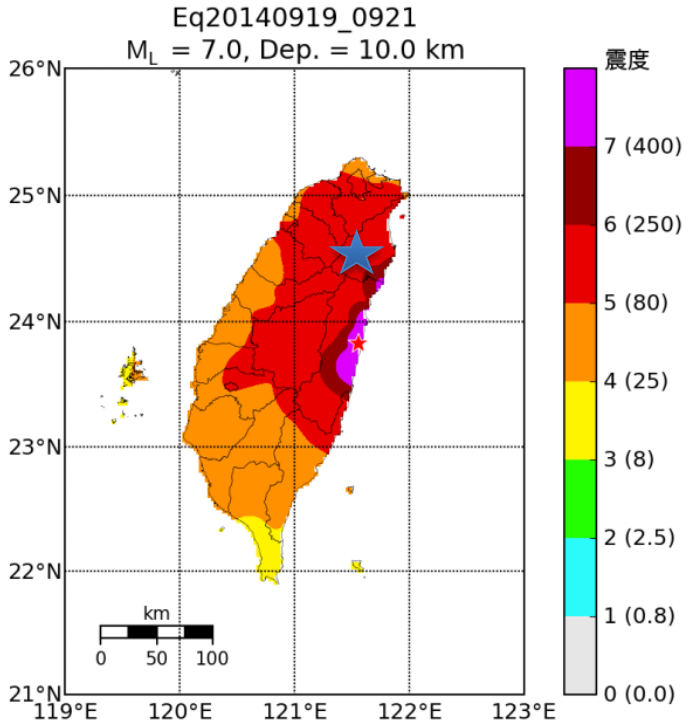


Figure 4. Seismic hazard map: Spatial distribution of PGA.

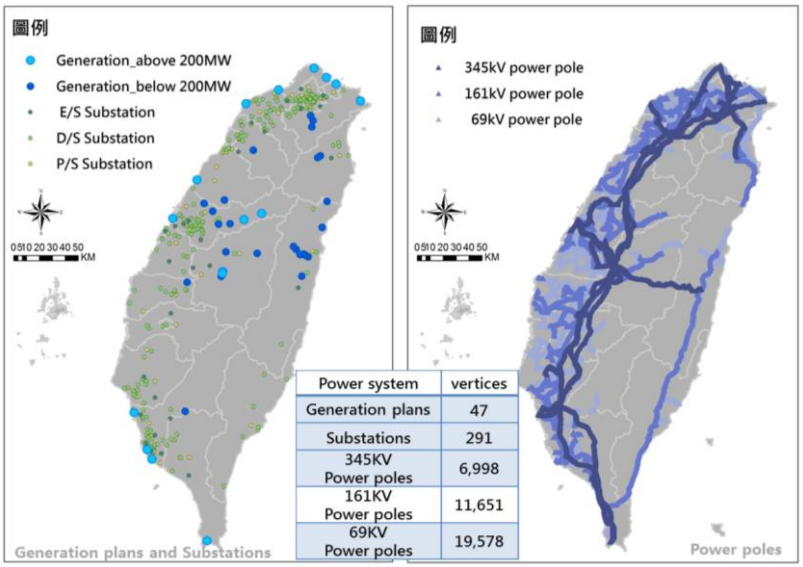
VULNERABILITY ASSESSMENT AND IMPACT SCENARIOS

TERIA is able to analyze and illustrate the direct impact scenarios of buildings, population, bridges, roads, and other infrastructures. The paper focuses on the results about power and water systems.

1. Inventory of lifeline systems in Taiwan

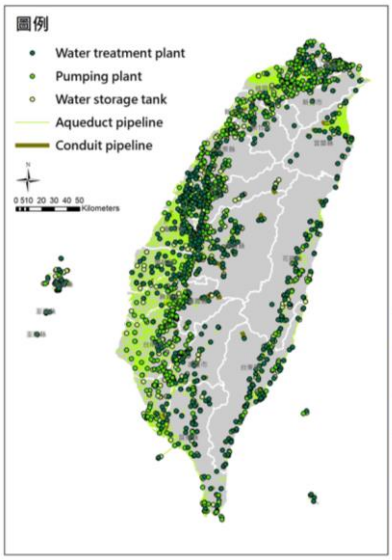
A key component of this study is the inventory data of the Taiwan water and power systems. The source data are gathered from the Taiwan Water Corporation and Taiwan

Power Company. The inventory data present here is the result of processing excel files into GIS data. The power system data consists of generation plants, substations, power poles, and distribution circuits. On the other hand, the water system data consists of water treatment plants, pumping plants, water storage tanks, and distribution pipes.



Power system	vertices
Generation plans	47
Substations	291
345KV Power poles	6,998
161KV Power poles	11,651
69KV Power poles	19,578

Figure 5. The GIS data sets of Taiwan power system.



Water system	vertices
Water treatment plants	547
Pumping plants	827
Water storage tanks	1,546
Aqueduct Pipelines	33,032
Conduit Pipelines	843

Figure 6. The GIS data sets of Taiwan water system.

2. Application for drill scenario

The areas for the drill scenario of National Disaster Prevention Day of Taiwan in 2014 included Yilan County, Hualien County, Taitung County. Hualien County is classified as a high-risk region where severe impact occured in the scenario simulation.

3. Fragility of lifeline components

The seismic assessment of lifelines systems is to quantify the direct damages related to the seismic hazard intensity. The vulnerability function in this study is probabilistic relationships based on the fragility curves provided in HAZUS-MH MR5(2010), SYNER-G(2011), and TELES(2012) [7,8,9], according the input earthquake hazard scenario [10].

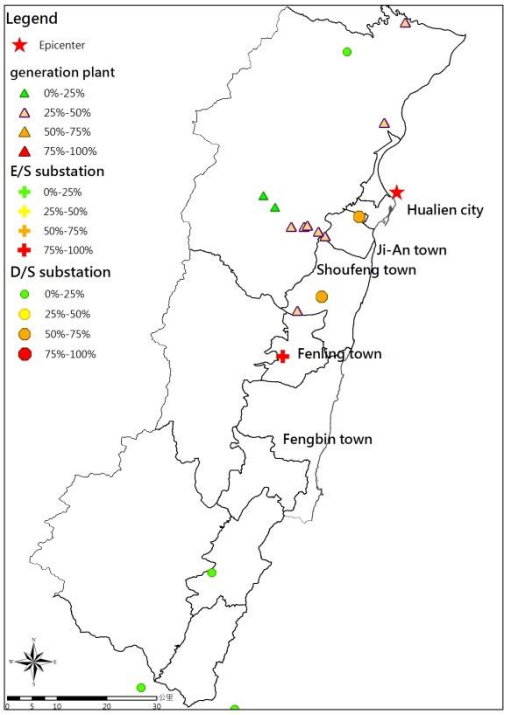


Figure 7. Distribution of expected damages to power system of Hualien county for the seismic scenario.

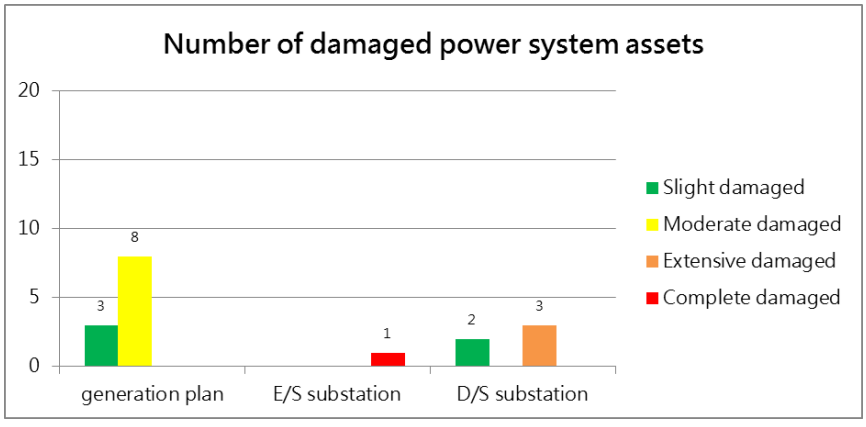


Figure 8. Number of damaged power system assets for the seismic scenario

Most power generation plants and substations response are undamaged. However, few substations are expected to sustain a serious damage under this seismic hazard scenario. This is due to the high values of the peak ground acceleration. According to

the damage state of the distribution circuits, it is able to compute how many people are affected. Power outage affected zone such as: Hualien city, Ji-An town, Shoufeng town, Fenling town, and Fengbin town, which are the most affected zones. Further, Fenling E/S, Shoufeng D/S, Sheng-An D/S, and Hualien P/S substations are severely damaged.. The estimated damage status for the power system is shown in Figure 7. The number of damaged power system assets is shown in Figure 8.

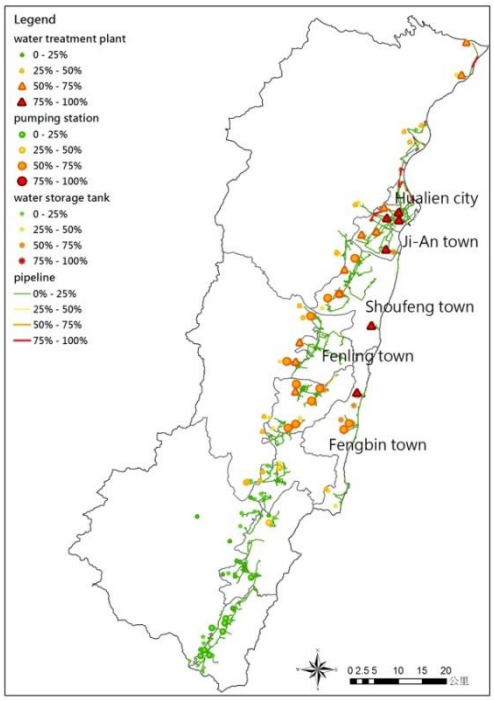


Figure 9. Distribution of expected damages to water system of Hualien county for the seismic scenario.

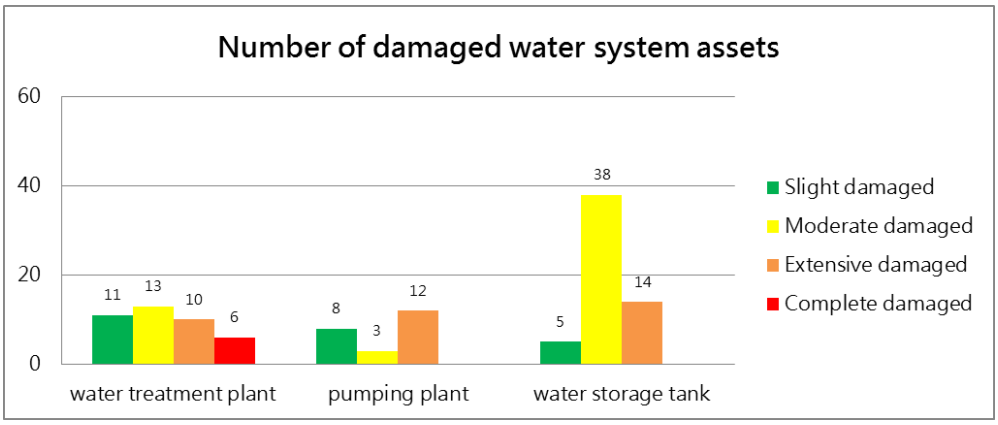


Figure 10. Number of damaged water system assets for the seismic scenario

The majority of water treatment plants, pumping plants, and storage tanks response are undamaged. However, few water treatment plants and pumping plants are

expected to sustain serious damage under this seismic hazard scenario. This is due to the high values of the peak ground acceleration. According to the damage state of the distribution pipelines, number of people affected could be computed. Water shortage affected zone such as: Hualien city, Ji-An town, Shoufeng town, Fenling town, and Fengbin town, are the most affected zones. Further, Shanji, Meiluen, Kuangwha water treatment plants are severely damaged.. The estimated damage status for water system is shown in Figure 9. The number of damaged water system assets is shown in Figure 10. The details of the scenario assessments have been documented in the research reports [11,12].

CONCLUSIONS

The task of earthquake impact scenario assessment is crucial and complex. This study introduces a GIS-based earthquake scenario assessment platform which aims to play a collaborated interface between the stakeholders of techniques and data collection. The objective of this unique platform is to furnish a comprehensive impact and damage scenario to fulfill the necessary data for planning disaster mitigation strategies and preparedness actions that make the cities in Taiwan more resilient to earthquakes.

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