SOLUTION-BASED SCIENCE & TECHNOLOGY PROGRAM FOR ASSISTING DISASTER RISK REDUCTION AND EMERGENCY RESPONSE IN GOVERNMENTAL SECTORS IN TAIWAN

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ABSTRACT**:** To introduce outcomes generated from science and technology to improve and strengthen the effectiveness and efficiency of governmental administration on emergency preparedness and disaster risk reduction usually needs to find some common grounds to pull people of two groups, academia and government, together for applying knowledge management. In this paper, the author will share experience of designing solution-based program and implementing strategies to meet the practical demands proposed by government in Taiwan. Especially, through scanning weak points of natural characteristics and insufficiency of administrative systems, the solution-based program built up the framework first in accordance with demanding needs to call for teamwork of government agencies for jointly solving the problems. For example of coping with hydro-meteorological disasters like typhoons, floods and precipitation-triggered landslides, the carried-out measures included applying improved numerical ensemble models to forecast trajectories and rain of typhoons, producing potential risk maps of inundation providing scenario-based estimation and conducting on-site field surveys of vulnerable slope land to identify risk levels. During the implementing processing, close partnership, mutual trust and interactive response are three key elements to succeed the integration with knowledge-based management and rescue-oriented operation. The best approach to build the strong connection between academia and government is through the joint operation during emergency response. Practically, emergency response operated by governmental officials always requests comprehensive and precise situation maps telling severity and demands of the affected areas. By introducing GIS-based decision supporting system and interpretation by academia into the Emergency Operation Center (EOC), it really helps the commander of EOC is able to have the whole situation awareness and scientific analysis. To brief the development of scientific program, the author will describe how to build up consensus and partnership by setting mission-oriented research topics and the progressive management to guide the direction of scientific researches. From reviewing the past practices, the author will also address the major considerations and challenges for designing, managing and implementing the solution-based program in assisting empowering capacity and capability of governmental sectors.

KEYWORDS: Decision Support, Disaster Risk Reduction, Emergency Response, Emergency Preparedness

1. CHALLENGES BY NATURAL DISASTERS

In Taiwan, earthquake, typhoon and landside are the three major disasters threatening life and property loss. During flooding season, May to October, typhoon and flooding accompanying with debris flow are the main natural threats. In 1999, the Chi-Chi Earthquake (ML=7.3), the most devastating one during the 20th century occurred in Taiwan. Beside the death toll over 2,500 and US $10.7 billion direct property loss, the infrastructure's destruction such as lifeline systems had brought a major impact on livelihood and economic activity. The degree of integrity for disaster reduction is directly related to the index of the governmental implementation about the public safety and property protection; therefore, the primary targets of disaster mitigation are Reduction, Preparedness, Response and Recovery. This article would describe the framework, coordination, technology and regulations for the central to local governments to carry out the emergency response in Taiwan. On typhoon attack, the assessment group would analyze hazard impacts, identify the areas with high disaster risk and suggest the appropriate response measures to the commander of Central Emergency Operation Center (CEOC) as the supports for decision-makings. The useful information provided by assessment group includes real-time report and estimation of rainfall, potential inundation area and possible debris flow basins. In 2004 with 9-typhoon invasion, the CEOC had successfully operated emergency response and conducted evacuation residents form endangered area.

In 2009, Typhoon Morakot, moderate scale, which initially moved toward Taiwan at fast pace with the expectation to quench the severe drought since early 2009 at its first appearance, nerveless it brought the record-breaking downpours in three days that triggered large-scale compound disasters including floods, debris flows and landslides accompanied with damage and interruptions of collapsed houses, power lines, communications and transportation. In southern Taiwan, over 700 people dead or missing were reported and isolated villages in mountainous areas increased the difficulty of search and rescue operations and drew a lot of public attention on recovery process. Because of the unprecedented catastrophe, there are emerging demands to remedy the existing systems, operation and policies of disaster risk reduction and emergency response, which need a compressive examination. Reviews of problems and insufficiency found during and after Typhoon Morakot identifies direction for future improvements, disaster governance and disaster risk communication that needs the efforts and contributions both by the newly-amended governmental framework and public awareness to carry out.

Therefore, how to enhance the capability and capacity of all-level governments by introducing science and technology is essential as frequent threats by natural disasters

2. EMERGING THREATS AND CHALLENGES IN CONSIDERATION OF 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 learning 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 living 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.

2.1 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).

2.2 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).

2.3 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 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 1.

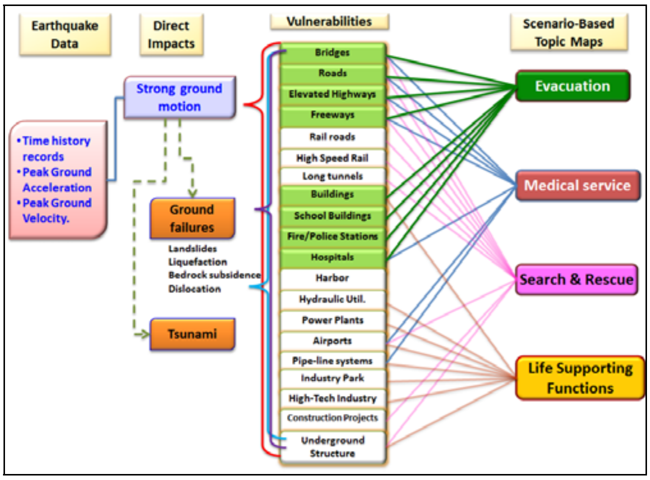

Figure 1 the basic considerations to produce scenario-based topic maps

2.4 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.

2.5 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 2. 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.

2.6 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 3. (Lin,2008; Lin, 2009)

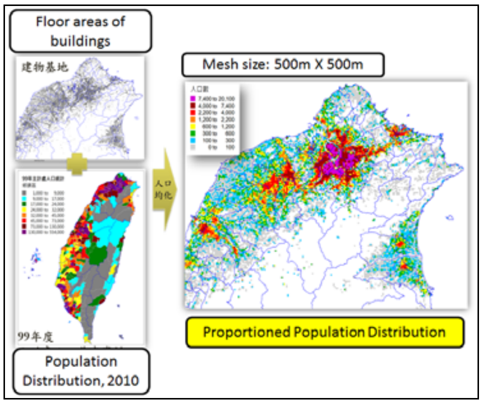

Fig.2 quasi-dynamic population distribution

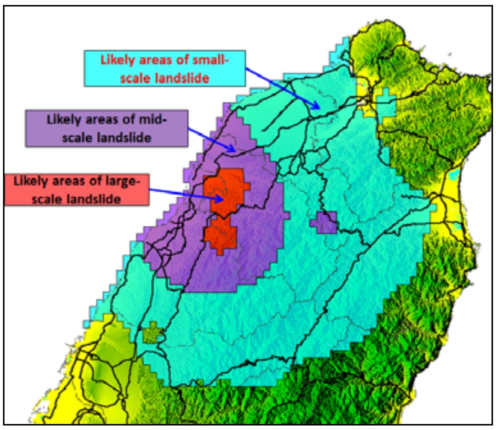

Fig.3 landslide potential map

3. COUNTERMESURES AGAINST HYRO-METEOROLOGICAL DISASTERS

As typhoon is the most frequent disaster to Taiwan, the operation mechanism for emergency response and tools for identifying disaster potential risk are two basic approaches to defend floods, landslides and debris flows trigged by torrential rains.

3.1 Operation mechanism for emergency response

As typhoon is approaching to Taiwan, according to the warning launched by CWB, the Central Emergency Operational Center (CEOC) would be activated and perform the nation-wide commanding center. The CEOC shall immediately report it to the summoner of the Central Disaster Prevention and Response Council. In turn, the summoner, depending on the gravity and nature of the disaster, may decide to create a Disaster Emergency Operation Center and appoint a command officer. To provide sufficient decision-supporting information for the CEOC's commander, the Assessment Group would coordinate the information among several government agencies, generate the assessment of the disaster potential, and contribute the suggestion of evacuation, in Figure 3. The main participating members of Assessment Group are CWB, Soil and Water Conservation Bureau, National Fire Agency, Water Resources Agency, Advisory Specialists, and the National Center for Disaster Reduction (NCDR).

NCDR, a technically oriented organization, provides the risk and vulnerability assessment of the impact of typhoon based on correlative information. In NCDR, cooperation from the meteorology division, the flooding & drought division and the slopeland disaster division would produce several analyses, the potential rainfall distribution, the areas of inundation and the debris flow, to supply the suggestion and advice in CEOC. The emergency operation of NCDR would last to the relief of typhoon threat.

The operations and decisions of the CEOC had demonstrated the effectiveness and contribution in reducing the number of death caused by the typhoon attack. For example, Typhoon Teraji in 2001 brought the 155 causalities, including death and missing, in Table 3. By comparison of Typhoon Nari in 2001, with the first operation and evocation suggestion of Assessment Group in CEOC, the death and missing had been decreased apparently. The value and contribution of full-functioned Assessment Group would play the important role in the emergency response.

3.2 Improvements after Typhoon Morakot

During the drafting stage of the "Disaster Prevention and Response Act", the main targets are to reflect the urgent requests urged by the general public and lawmakers after the 1999 Chi-Chi Earthquake, but there are always new demands which appear when another major disaster takes place. Lessons and experience learned from Morakot once again uncover the insufficiency in exiting law and framework. Couples of weeks after Morakot, heated debates and arguments were hitting the headlines to express the widespread dissatisfaction about the disqualified responses and operations by all levels of government. Finally in July 2010, the Legislative Yuan certified the revised version, which includes significant modifications to path and reinforce the operating mechanism of disaster management in Taiwan by adding the element of "whole government participation". The major changes include:

1. Promoting the efficiency of execution at central level government by strengthening the operational function of the Central Disaster Prevention and Protection Commission and establishing the Office of Disaster Management (ODM) under the Executive Yuan, which is the

centerpiece of the amended act.

2. Strengthening and emphasizing the obligation and responsibility of local governments on disaster reduction and emergency response by updating the relevant regulations in accordance with the Local Government Act are the steps to build up close interaction between local and central governments.
3. Within the amended articles, the Central Disaster Prevention and Protection Council of District-level and Township-level governments are required to set up Office of Disaster Management in order to conduct disaster reduction and emergency response including emergency evacuation and evacuation, situation reporting, quick recovery and clean-ups of environment.
4. The National Fire Agency will be transformed into the Disaster Prevention and Protection Agency for further facilitating missions assigned by laws and fulfilling the whole-government governance. And the National Rescue Command Center is responsible for coordinating and dispatching domestic resources of search and rescue, and conducting the air-lifting of emergency medical service.
5. Assign the National Disaster Prevention and Protection Expert Adversary Committee and the National Science and Technology Center for Disaster Reduction as the advisory board of science and technology to the Central Disaster Prevention and Protection Commission and Council, the two units are financially supported and official operated by the National Science Council.
6. To realize the purpose of maximizing the contribution by private sectors, the Civil Defense Systems will be parts of framework for disaster management system.
7. The Executive Yuan requested by law is obligated to submit the "White Paper of Disaster Prevention and Protection" to the Legislative Yuan annually, which identifies the direction of National prospects and goals on ensuring people's safety and prosperity.
8. Amending the articles of Disaster Prevention and Response Act are designed to authorize the military forces to actively respond to disasters and optionally recruit veterans for supporting emergency operations.

3.3 Improvements of Emergency Operation at Central Level

After the Typhoon Morakot, the general public has raised dozens of question marks to the operations of all levels of government for asking the answers about how to ensure people's lives and properties. Among the questions, information integration, emergency operation, multi-channel communications, situation reporting system and measures for large-scale disasters are the primary phenomenon to discuss.

Within last ten years, abundant information systems for disaster risk reduction and emergency response have been established by governmental agencies. For examples, the Water Resource Agency, the Central Weather Bureau and the Water and Conservation Bureau have continued investment on improving systems for upgrading forecast, monitoring and early warning. But the last-mile implementation, information integration, is a long-standing idea which requires a neutral agency to maintain a platform that is designed for accommodating all information and databanks and demonstrating the data with geo-spatial properties.

By surveying the emergency operation during Typhoon Morakot, the gaps have been identified in several aspects. Lack of commanding-based decision supports, commander in EOC received reports by individual operational groups respectively and there were insufficient integration and miss-links that would help to present a comprehensive situational picture during emergency. Beside channels and platforms among governmental agencies required, the tools for improving risk communication between citizens and governments to build up mutual trust are also crucial remedy to enhance emergency preparedness. Nowadays, with rapid development of Information-Communication-Technology-Based industry, the mechanism of real-time information sharing and exchange is the key element for accelerating operation and upgrading capacity as a joint task force of cross-unit are working on emergency. To better the multi-lateral understanding and collaboration, the routine workshops or seminars should be welcome to eliminate possible voids during real operations. For completing the information collection, the geo-spatial data, demographic information with social-economic ingredients, locations and weakness-sweeping of critical infrastructures, real-time monitoring, early warning, vulnerability assessment and forecasts are all listed as the priorities to be retrieved. Currently, the integrated information is under construction and already acquires supports of governmental agencies.

In accordance with the reforms of information integration, the restructuring of Central Emergency Operation Center (CEOC) has been implemented to promote the operation efficiency and respond to the questions raised after Typhoon Morakot. The Fig. 4 illustrates the latest organization framework of CEOC and the major modifications include: Situation Assessment Group is responsible for integrating and summarizing the developing situations, real-time monitoring data, forecast results and risk potential assessment to present comprehensive suggestions in evacuation, reinforcement dispatch and warning zones to commander of CEOC through discussions among participating governmental agencies and NCDR. In Situation Assessment Group, it also has been authorized to summon institutions and agencies which have the capacity and capability carrying out the aerial surveillance like planes, unmanned aerial vehicles and satellites to provide the images of affected areas by prompt operation. Another major change, Web Information Collection Group, is designed to actively gather scattering messages, requests, case reposts and information posted in bloggers, Facebook, Twitters or social networks by netizens to avoid the embarrassing condition last year as the emergency call centers were overwhelmed when tens of thousands people called for case reports simultaneously.

4. CONCLUSIONS

Since the enforcement of “Disaster Prevention and Response Act” in July, 2000, the first article of it clearly describes the spirit, “the Act has been incorporated for the development and improvement of a disaster prevention and response system of functions to protect the safety of the people’s life and properties and conservation of the homeland.” Though the Act absorbs the experience and practices of existing system and the advanced countries, but everlasting efforts to improve the system are definitely vital for tightly connecting planning and implementation, intensely boosting public and private partnership, and gradually improving concept of risk communication.

By “Learned from Disasters”, the continuous improvements of disaster management after each major events are elaborate for being close to the needs of people and whole society. Through the amendments of laws and regulations, enforcement of new countermeasures and mechanism, and increase of emergency operations, but more requests and suggestions are strongly proposed by the general public for retrofitting the current systems and mechanisms to fit the societal expectation. The focal points include:

1. Enhancing cooperation and collaboration between the local and central governments: In face of unpredictability of natural disasters, common consensus should be routinely reached at all levels of governments to fully guarantee seamless collaboration during emergency. Through building up mutual trust, fluent communications, in-time information and situation awareness, both of local and central governments will effectively and collaboratively assist people in urgent need. An obvious example to tell why the whole-government participation is an essential element of state-of-the-art disaster management is information sharing. Although the central government might operate the advanced information system, but the system heavily relies on real-time inputs and simultaneous feedbacks from the local governments. Otherwise, an empty information system is a mere toy of technology.
2. Enrooting and promoting the concept of early evacuation: Considering the sever devastations left by Typhoon Morakot in the affected areas, the critical thresholds of accumulated rainfall leading to landslides or flash floods are to be much lower than the past, especially in the communities and villages with high risk potentials. As consequence, how to further mitigate impacts by early evacuation with collaboration between local governments and residents is what we had learned from Typhoon Morakot. To ensure a safe early evacuation, two pre-conditions have to be addressed for safeguarding the safety of evacuees and emergency responders: Frist, evacuation in day time; Second, no traffic blocks en route to shelters. For achieving it, the incentives to local residents are necessary with better shelter management plus humanitarian considerations, detailed evacuation plans and cross-unit collaboration. And well-designed evacuation plan must reflect the local needs and characteristics to effectively lower the possible risk and casualty. By throughout promotion and actual implementation of early evacuation during the attack of Typhoon Fanapi, 2010, through fifty houses were buried by mudslide in Laiyi Township of Pingtung County, but no casualty reported. Because of almost twenty-four hours prior to mudslide engulfing the village, all villagers had been safely removed by the successful joint operation of military force and local government. It is a clear and obvious proof of importance of early evacuation by active action.
3. Sharing integrated information with sufficient geo-spatial parameters: In recent years, all levels of governments have been investing over billion dollars on information system and databank related disaster reduction and emergency preparedness, but the lateral coordination seems to be the last mile to link systems for comprehensive application. To have a coordinated joint operation during emergency, the add-ons of integrated information system through multi-lateral exchange will bridge the gaps existing between central and local government to effectively strengthen the information communication and efficiently deploy resources and reinforcement. Therefore, information and situations with geo-spatial parameters will easily display the current situations and urgent demands on the GIS-based systems that should be gradually carried out by the Emergency Management Information System operated and maintained by the National Fire

Agency.

4. Improving understanding of risk communication: In recent years, the risk potential maps are more transparent to the general public by the requests of understanding of surrounding hazards. However, only risk perception is not enough to lead to low risk life, change of behavior and attitude toward disaster reduction is appropriate for people who live with threats of natural hazards.
5. Proposing strategies for urban disaster reduction: Nowadays, more than sixty percent of people in Taiwan live in urban areas where is densely populated, capital-intensive, highly developed and political and economic center. On the other hand, urban areas are more vulnerable to and easily affected by natural disasters like earthquake or urban floods. Evaluation of new development projects and urban renewals should take account of disaster risk to secure the safe growth of urban development. In 2009 and 2010, there are several cases of urban floods in the central and southern Taiwan, which precisely exposed weakness of cities including aging facilities designed by obsolete codes, poor maintenance and unprecedented rainfall. The last factor could be worsened by climate change and it is crucially required to find the solutions by adaptation strategies.

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