A Discussion on the Characteristics, Impacts and Emergency Response of Chi-Chi Earthquake

LIANG-CHUN CHEN
Associate Professor, Institute of Building and Planning, National Taiwan University
Project Co-Director & Group Leader, Mitigation Management System

ABSTRACT

Chi-Chi earthquake is the strongest earthquake hit Taiwan in the last hundred years period and caused significant impacts, and it also tested the four-level system with a real and severe situation. Under this condition, there are three major purposes of the paper: the first, to illustrate the conditions and characteristics of the disaster; the second, to illustrate the response of the central and local governments and the civil organizations in the first 10 days after the disaster. Lastly, we'll discuss the social and economic impacts of the Chi-Chi earthquake on the hazarded area, and provide some possibilities for the future.

KEYWORDS: Chi-Chi earthquake, emergency response, hazard mitigation.

1. Introduction

1.1 Background

Chi- Chi earthquake, recorded ML 7.3 on the Richter scale by the Central Weather Bureau while 7.6 by National Earthquake Information Center of the United States Geological Survey, hit central Taiwan area at 17:47 GMT, Sep. 20, 1999(Sep. 21 at 1:47 AM local time in Taiwan). It is the strongest earthquake hit Taiwan in the last hundred years period, and also the first massive earthquake after the modernization of Taiwan. Although the natural disaster from typhoons, thunderstorms and earthquakes are not rare here, Chi-Chi earthquake still caused significant impacts. During the past decades, it is getting complicated of the disasters caused by natural hazards, widely spread fire and manufacturing factory accidents, to deal with the situations, a three-level system for hazard prevention and mitigation is proposed. The Chi- Chi earthquake tested the system with a real and severe situation. It is important for the ones who concern hazard prevention and mitigation to scrutinize how the system works.

1.2 Objectives and Methods

By means of examining the actions of the central and local governments after the earthquake, the major purpose of the paper is to provide possibilities for the follow-up research concerning the deal of huge natural disasters. Specifically, the paper collects and analyzes the investigation materials and interviews the related persons. Firstly, it is illustrated in the paper about the conditions and characteristics of the disaster. Secondly, the response of the central and local governments and the civil organizations after the disaster have been

compiled along the time dimension from September 21 to 30. Lastly, we'll discuss the social and economic impacts of the Chi-Chi earthquake on the hazarded area, and make suggestions for future improvement of Taiwan's hazards prevention and mitigation systems.

In addition, since the hazard area is very broad, Puli is selected as the empirical case to have a closer look of the emergence response of local government. We interviewed people who worked in the hazard area to compile the main tasks during the 10 days after the earthquake hit.

2. Description of the Condition of Chi-Chi Earthquake

2.1 General Description

The preliminary epicenter for Chi-Chi earthquake locates at latitude 23.81 degrees north and longitude 120.9 degrees east, 12.5km from Sun Moon Lake, a famous scenic spot in Nantou County, or about 150 kilometers south-southwest of Taipei. The depth of Chi-Chi earthquake is about 7 to 10 kilometers and the magnitude is ML7.3 (CWB). It was caused by the Chelungpu Fault shown in figure 1, which is about 105 km in length and extends across Hsinchu, Taichung and Nantou Counties). From the facts that the maximal vertical movement reaches 11 meters and the maximal level movement reaches 10 meters, we can imagine how strong the destructive power was.

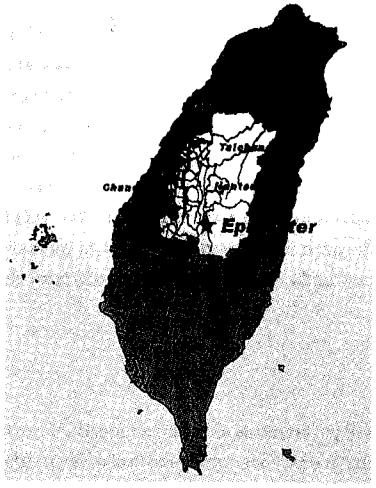
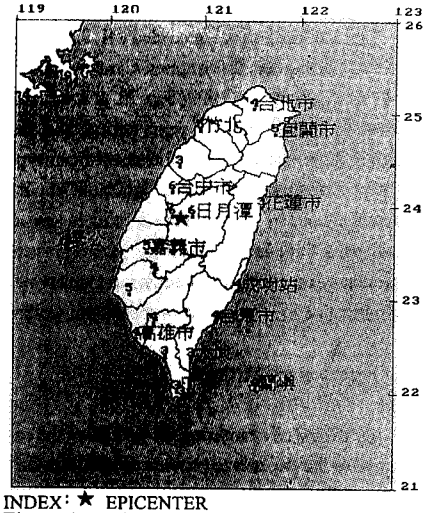


Figure 1: the Chelungpu Fault and the main disaster area of Chi-Chi earthquake.



INDEX: ★ EPICENTER

Figure 2: The location of the epicenter of Chi-Chi earthquake.

The earthquake caused substantial damage and heavy casualties on this island, especially in central Taiwan. In summary,

- Death toll: 2,415 persons (Nantou County 891, Taichung 1,175)
- Missing: 29 persons

Subtotal: 2,444 persons

- Wounded: 11,305 persons (severe wounded[1] around 700)
- Affected: around 310,000 persons, about 1.4 % of the total population of Taiwan
- Building damage: collapsed 51,711, damaged 53,768[2], subtotal 105,479 (28,217 collapsed and 28,974 damaged in Nanyou; 18,608 collapsed and 18,452 damaged in Taichung)
- Property damage[3]: 341.2 billions NT dollars, around US$ 10.7 billion

2.2 The Characteristics of the Earthquake Disaster

As described above, Chi-Chi earthquake caused significant loss in Taiwan. Moreover, the characteristics of the disaster area are categorized as following:

1) Characteristics of the disaster area

i、 The hazard area is broad

The length of Chelungpu Fault locates from Juoshuei River to the north rim of Da-an stream, passing through Tsaotun, Chushan, Mingjian, ChungHsing HsinTsun, Tsautuen, Wu-Fung, Taiping, Da-Kung, Fengyuen, Shihkung, Tunghsing, Dongshi, and Drou-Lang, which lasts over 105 kilometers; and Chelungpu

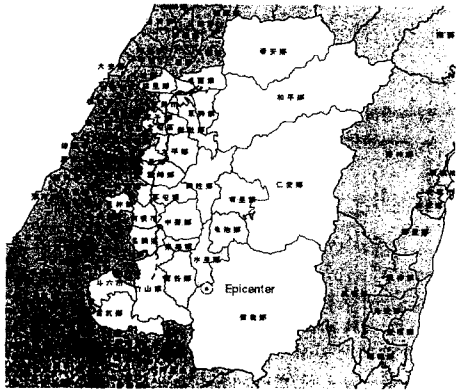


Figure 3: The townships of the main disaster area.

[1] Wounded who have to be hospitalized over 30 days.
[2] according to current regulations.
[3] including property and business loss but not including casualty, business invoice loss and historical and ecological damages.

Fault is a thrust fault that pushes from east toward west. Therefore, the area on the eastern side of the Chelungpu Fault encountered strong shake. The main disaster area include Nantou County, Taichung County, Beituen district of Taichung City, Dou-Liu City and Kukung township of Yunlin County, Yuanlin township of Changhua County, Juolan and Taian township of Miaoli County, totally 90.5 square kilometers . (Figure 3)

ii、 The hazard area attributed small villages and agricultural areas

In the broad hazard area described above, most parts are not urbanized areas. Only Puli (population 88,641) and Tunghsing (population 59,013) [4] are major towns, while others are small towns. Among these areas, only few of them have the functions of local commercial activities, while most of them are daily living and commercial center and agricultural and forest areas.

iii、 Most of the hazard areas are remote and sensitive mountain areas

Between the Chelungpu Fault and the Central Mountain area, most are hills and steep cliffs besides the tableland area aside the fault. They are the areas of remote villages, where the geology is fragile and sensitive.

iv、 Most of the hazard areas are multi-culture and scenic industry areas

In addition to the attributes above, the disaster area is also the place of multi-culture area including aboriginal, Hakka and Ho-lo. The famous sight-seeing spot, the Sun Moon Lake, locates in the area. The area is full of scenic resources that make the scenic industry of the area prosperous.

2) Characteristics of earthquake damages

i、 Considering the magnitude of this terrible earthquake measured 7.3 on Richter scale, the death toll was only 2,444 (includes missing). The main reasons cause this result, as discussed above, can be summarized as following: (A) the most affected areas near to the Sun Moon Lake, where is a low population, mostly rural and mountain area, (B) the occurrence time is 1: 47 a.m. when most of people had fallen asleep and most of commerce activities were ceased. Therefore, the number of death was not very severe.

ii、 The initial actions of emergency response and rescue were very difficult to proceed because the affected area was so broad that covered most part of middle Taiwan's

[4] Based on the population of Sept. 1999

rural and mountain area, where the populations and the communities were located scattering, the traffic conditions were poor, and the communication systems had not been well established. Therefore, the emergency and rescue activities were not performed smoothly at the very beginning.

iii、 This earthquake caused multiple disasters that included the urban type damages and the rural and mountain type damages, such as:

a. Different type damages to private buildings: The damage types by the different kind of buildings included the clay brick buildings and brick houses in rural area, the connected low-rise multiple dwelling houses in suburban area, and the middle- and high-rise apartment buildings in urban area.

b. Sever damages to public buildings: More than 125 elementary and junior high schools were destroyed, as well as several local administration buildings were collapsed. As a result, the entire education and local government's functions were down after the earthquake.

c. Sever damages to lifelines and infrastructures: Most of high-voltage power systems which included the generating plants, major transformer stations (including Chun-liao high-voltage transformer station), the power cables, and the power line towers were damaged. Therefore, more than two third of the entire Taiwan areas were out of power from days to weeks. In the meantime, due to the offset of faults, landslide and falling rocks, lots of the highways and roads were damaged or obstructed.

d. Sever geo-technical hazards: due to the fault rupture, the strong surface shaking, and the soft soil layer on the top of faults this earthquake cause a lot of geo-technical hazards, such as:

- The vertical or lateral offset between both sides of fault that result the sever building or structure damages and the limitation of rebuild the buildings or structures.
- The huge landslides at Tsaoling and Jiu-fen-er mountains areas block the several streams and rivers that formed several temporary reservoirs. When the reservoirs now are fully filled with the collected water, they may cause the dam to collapse and flood over the down stream areas.
- The conditions of large volume of loose rocks and the soft soil created on this earthquake are getting worse, especially during heavy raining days or aftershocks that might cause the continuing falling rocks and debris-flows. The falling rocks and debris-flows damage the roads, houses, and communities that cause the secondary hazard.
- Due to the strong ground motion and the soil structure, lots of buildings' subsidence and tilting were caused by the soil liquefaction in Taichung Harbor and Yuanlin Township areas.

- Because of the strong ground motion, fault rupture and landslide, most of agriculture products and farming equipments, as well as the irrigation and road systems were destroyed in the affected areas that cause the major farming industry was shrunk even stopped.

e. In the meantime, it should be noticed that the fire following earthquake was not the key issue in this earthquake. The possible reasons are: (A) the occurrence time at 1:47 a.m. when the fire or heating sources were very few, (B) even there are several gas leakage cases, however, due to the large area and the long time period without power supply, it did not cause sever fire following earthquake.

iv、 Most of administrative systems were down within the affected areas that prevented the local government from the initial emergency response. Because most of affected areas are located in the rural and mountain area, they all suffered the shortage of the manpower and resources in the regular time that cause most of local governments poorly to prepare the emergency response. Also, during the earthquake most of the City/Township Halls were collapsed and lots of local governments' staffs were also the victims of the earthquake. Therefore, at the very beginning the local governments of affected areas can't perform the expected functional operations in the initial emergency response activities.

v、 After earthquake, the industries' shrinkage and unemployment became the key issues. Because farming and agriculture are the major industries within the most affected areas, where commercial and other industries are relatively insignificant in these areas, once the farming and agriculture out of business or even reproducing the products, it needs considerable time and supports from other industries to bring back to normal situations as they used to be. Therefore, the problems of industry recovery and the unemployment are very difficult to deal with in those out-of-the-way villages.

vi、 Because a lot of aborigine villages and farmers were located scattering within the affected area. The effects of earthquake destroy a lot of plantations that result not only the property loss but also the property ownership exchange and the reconstruction of the ethnic culture. Those non-substance losses cause the earthquake damage situations more complicated.

In conclusion, the damages of Chi-Chi earthquake include not just the sever damages to the substance environments (buildings, structures, public facilities, the geotectonic environments), but also the damages to the social and economical environments (industries' shrinkage, unemployment, ethnic cultures, the land use). The aftermaths of Chi-Chi earthquake turn into very difficult and complicated problems and not easy to solve.

3. The Initial Activities for the Emergency Response

3.1 The Taiwan Existing System for Hazard Mitigation and Response

Taiwan is subject to a variety of natural and technology disasters frequently and the magnitude of these disasters is getting bigger recently. Before 1994, the governments in Taiwan usually established ad-hoc emergency response teams immediately before or after the disaster (e.g., typhoon or earthquake). After the disaster threat had lessened, those teams were disbanded. Thus, Taiwan lacked a long-term and comprehensive disaster mitigation and response system. In 1994, after the earthquake in Kobe City, Japan, a "Disaster Prevention and Response System" (Central DPRS) was mandated in Taiwan by the central authorities and carried out by local governments to lessen the impact of disasters.

Three levels of governmental hazard mitigation and response system were established (see Figure 4): Central, County/City, and Township/Shiang. The Central Hazard Mitigation Council (Central HMC) directs each level to organize Hazard Mitigation Councils (HMCs). The Central and County/City levels are also directed to organize an Executive Committee and a Technical Advisory Committee under and supervised by its HMC. The Executive Committee is the administrative organ of the HMC, and the Technical Advisory Committee provides consulting services for disaster mitigation and response activities. The director of each individual Executive Committee is responsible for organizing Local EOC when disasters strike. The Local EOC should in charge of the disaster information collecting and reporting, and commanding / coordinating / directing the emergency response activities.

To ensure orderly execution of hazard mitigation and response tasks and to increase hazard response capabilities, Central HMC should elaborate "Primary Disaster Prevention & Response Plan" (Primary DPRP) also directs relevant public agencies to elaborate "Specific Disaster Prevention & Response Plan" (Specific DPRPs) and local governments (County/City & Township/Shiang) to elaborate "Local Disaster Prevention & Response Plan" (Local

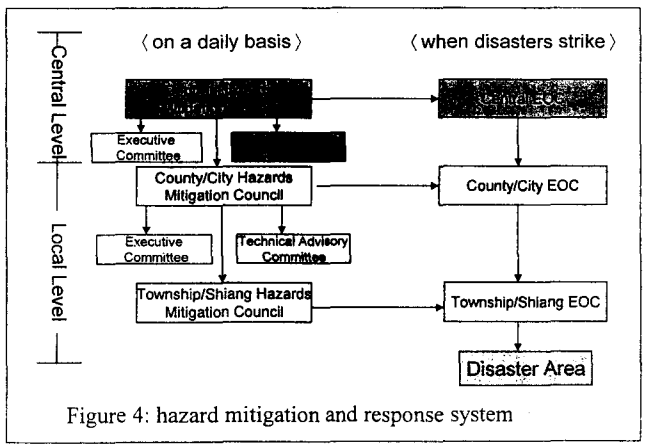


Figure 4: hazard mitigation and response system

DPRPs) reflecting regional characteristics and local needs for the hazard mitigation, preparedness, response, and recovery.

3.2 The Chi-Chi Earthquake and the Initial Response Activities

The strong movement of earthquake killed thousands, fell more than 100,000 buildings and caused many sever landslides. The earthquake was an unprecedented disaster in the history of Taiwan. A series of surveys were conducted by our research teams to investigate the entire governmental disaster response situations, including collecting relevant information, interviewing relevant staffs of all level governments, and documenting all the data according to the time sequence. This paper will reveal the results of this research. Owing to the limitations of manpower and time schedule, the objectives of this research were focused on the actions of local level governments (County/City & Township/Shiang) within 10 days after earthquake. The results can be summarized as the contents of following Table 1.

Table 1 The Response Actions Taken by All Level Governments

Unit / Time	central government	Nantou County government	Puli Township	Conditions
88.09.21 01 : 47				• Earthquake hit • Puli was isolated because of the road disconnection • Information collection was difficult because of power failure over 2/3 of Taiwan
02 : 00	Central level EOC established in the National Fire Administration		• Emergency Response Center established in the fire department	
02 : 15	The premier arrived Central level EOC and gave 9 instructions.			
03 : 00		County level EOC established in the county stadium		✱ Military force began the work of the relieve of victims of the disaster
04 : 30		The chairmen of Taiwan Province arrived the county emergency center		
05 : 30				The communication of Puli was totally disconnected because of the power failure
06 : 00	The vice minister was in charge of the heading command post		Township level EOC established	
In the morning	• The president and premier arrived the county stadium.	• Emergency center established in the county stadium. • Satellite phones established in the county stadium.	✱ The major road temporarily restored with the assistance of military force • Supplement goods arrived and gathered in the distribution center in front of township office.	• A large number of wounded people entered the veteran hospital and the Christian hospital.
17 : 00	Executive Yuan gave 15 instructions of disaster relief.			
In the afternoon			✱ Police and military force brought out the wounded to hospital by helicopters.	

Unit / Time	central government	Nantou County government	Puli Township	Conditions
			• The township chief hold a disaster relief meeting	
21 : 00	The minister of the department of interior affairs communicated with the heading command post with satellite phone and gave instructions.		✱ The military force set up heading command post in the Puli elementary school.	
88.09.22 08 : 00			The staffs of township office and the military were joined and moved to the Puli junior high school.	Japanese rescuing team arrived Puli around 8:00.
15 : 30				Telecommunication restored.
19 : 00	The deputy premier of the Executive Yuan introduced the major implementation of disaster relief to the press.			
(09.22)	• The president decided to establish the supervision center of 921 earthquake., and the vice president was assigned as the supervisor. • The ministry of communication provided 20 satellite phones and 800 wireless intercoms to the disaster area.	The county government reviewed the relief needs, re-integrate the forces and assign the supervisors to the disaster areas.	• Epidemic prevention center established in the Puli Junior High School. ✱ The military and civil organizations took over the disaster relief work from the exhausted government staffs. ✱ Because there was no prosecutor in Puli, over 80 death certificates were issued by the director of township health centers. ✱ Part of the supplement goods moved to the Puli Junior High School. • The township health center began to survey shelters .	There was no prosecutor in Puli at the time, many victims' bodies were decaying and couldn't be properly buried, because their death certificates hadn't been issued.
88.09.23	• The vice premier of Executive Yuan declared that a donation account would be setup and daily review of the work of rescue would be proceeded and announced. • The first meeting of the supervision center of 921 earthquake hosted by the vice president. • Executive Yuan decided the principle of supply and compensation initially (fifty thousand dollars per death, twenty thousand dollars per severe wounded, twenty thousand dollars per collapsed household) and provide temporary houses and allowance funds of houses to solve the problem of victims' residence	• Sanitizing the environment. • The review of disaster relief operation by the county government and the military force.	• Initial survey of the shelters had been finished. • The staffs of the department of Health start the sterilization.	
88.09.24 in the morning	• A meeting for Disaster victim settlement hosted by the premier of the Executive Yuan. • The second meeting of the supervision center of 921 earthquake hosted by the vice president.	County government staffs went to the local heading command posts and distributes disaster subsidy.	• The rescue team from Pintong county arrived Puli. • Puli county started the sterilization work with the help of the department of health and the bureau of environmental protection of Taichung.	
88.09.25 in the morning	• Executive Yuan convened provisional meeting to suggest the president to issue the emergency order, and assign three government committee members for			

Unit / Time	central government	Nantou County government	Puli Township	Conditions
	supervision • The meeting of supervision center of 921 earthquake hosted by the vice president, and it was indicated to increase the death compensation to one million dollars per death.			
20：00	The president signed and promulgated the emergency order, valid during 9/25/1999 and 3/24/2000.			
88.09.26 07：52				A ML6.8aftershock caused 7 death and 60 wounded.
In the morning	The death compensation raised up to1 million NT dollars by the Executive Yuan.			
In the night time	The president hosted the 4th leading officers and indicated to establish the post disaster reconstruction committee			
(09.26)	• An investigation of the amount of disaster victims who needed the temporary housing had begun.		* With the assistance of military, all supplement goods were moved and gathered in the stadium of the Puli junior high school.	
88.09.27 in the morning	The preparation meeting of the 921 disaster reconstruction committee convened by Executive Yuan. According to the conclusions of this meeting, the premier of the Executive Yuan served as the leader of committee member and the vice primer of Executive Yuan as the secondary committee member. Moreover 「The supervision center」 was renamed as 「The post disaster reconstruction committee」			
In the afternoon	Executive Yuan declared and assigned each deputy chief of the sectors to assist every county and township to establish the post disaster reconstruction group.			16：00 heavy raining in Puli 17：00 raining turned into hailstones
(09.27)		County government signed contracts with Tzy-Chi charity organization that the government provided lands and Tzy-Chi would be responsible for building temporary housing for victims.	* Sterilization by the military forces • Vaccine injection began. * The management of supplement goods was taken over by the military force.	
88.09.28	The operation of 13 working groups under the post disaster reconstruction committee began to function. The deputy premier of the Executive Yuan was assigned to establish the central office of Taiwan immediately.	* The reconstruction command sector was established in Nantou county stadium by the military force, and it assisted the second stage of rescue work. They started to restore roads, remove collapsed buildings and build temporary houses etc.	* Six reconstruction sub-command posts established by the military force	
88.09.29	The central office of the post disaster reconstruction committee was established in Taichung by vice president. The first meeting was hold at 14:00 in the central office.	The first temporary houses began to construct which was assisted by civil organizations.	Puli reconstruction working group established	
88.09.30	The second meeting of the 921		One-week sterilization of the	

Unit / Time	central government	Nantou County government	Puli Township	Conditions
	post disaster reconstruction committee was hold by the central office and set up the criteria of destroyed buildings, victims' compensation, and rental compensation.		Puli township had been accomplished.	

3.3 The Mobilization and Participation of NGOs and Volunteers

Because the Chi-Chi earthquake is an unprecedented disaster in the history of Taiwan and the characteristics of damages are so complicated which discussed above, although Local governments and military troops proceeded the emergency response and rescue operations base upon their responsibilities as soon as possible, but these activities were not performed smoothly and orderly according to their Local DPRP. Under this circumstance, the private sectors released the most powerful energy of mobilization and participation that has ever seen in Taiwan. A lot of non-government organizations (NGOs) and volunteers contributed to the many emergency response and post-earthquake recovery operations that the public sectors couldn't fulfill after the Chi-Chi earthquake. The major operations that the NGOs and volunteers worked on can be summarized as followings:

1) The donations to the earthquake disaster rehabilitation

After the earthquake, numerous people, private companies, and non-profit organizations donate money directly to the affected areas for the reconstruction and rehabilitation of houses and communities. It is very difficult to figure out the exact total amount of the donations, but base upon the statistics made by "National Alliance for the Post-Earthquake Reconstruction" (NAPER) which consist of several civil groups shows there are more than 331 special accounts for the different donations and the total value of the donation was over 28.9 billion NTD by the end of March, 2000. If local governmental raising funds and the adoption fees for the reconstruction of schools are added to this amount the total value of donations will goes up to 35 billion NTD (or 1.1 billion USD).

On the other hand, at very beginning there are lots of resource including food, daily supplies, equipments for search & rescue, and medical materials & medicine that are flooding into the affected areas. Therefore, the total value of all the donations (include the materials and money) goes to the affected area from the entire country is enormous.

2) The participation of NGOs and volunteers

Because the affected area was so broad, all the NGOs and volunteers moved freely and

very flexibly within the affected area. Therefore, it is very difficult to calculate the exact number of all NGOs and volunteers. But from the following explanations we can recognize another aspect for the analysis that what kind capability of mobilization for NGOs and volunteers in Taiwan society.

i、 The characteristics of the participants

The NGOs and the volunteers that went to affected areas were almost the religious groups that concern and care the spiritual and religious beliefs of people, the charity groups that took care and looked after the people who needed help, the search & rescue groups that helped people free from incident events, or the emergency medical service groups that provided the emergency medicine to the victims of incidents. In addition to these groups, there were a lot of NGOs also involving the emergency response and recovery operations very deeply, such as the research institutes, academic groups, professional groups (e.g., architecture, engineer, lawyer etc.), and the non-profit foundations and societies. It can be seen that the entire society and possible resource were mobilized to help the people and the communities within the affected areas during the post earthquake period.

ii、 The mobility of the participants

The NGOs are absolutely different from the governmental organizations that are limited by lots of regulations and codes. Therefore, the NGOs can move within the affected areas very fast. For example, at the early morning on September 21, 1999 after earthquake, in Puli Township, Nantou County, even the entire township was damaged severely, several local religious groups and communities' volunteers were already organized to prepare the hot meals for the panic victims and hungry emergency medical persons. When the roads and highways to the Puli were repaired to open, lots of the rescue groups, medical groups, and charity groups were flooding into the Puli area to rescue and help the victims. In the first day, more than 10 rescue and medical stations were set up for the victims. To sum up, the records reveal the facts that the NGOs and the volunteers are more flexible and mobile than the governmental organizations.

4. The Social and Economic Impacts of Chi-Chi Earthquake

Chi-Chi Earthquake, the largest scale earthquake ever occurred in Taiwan in the nearest one hundred years, had broad and deep impacts on Taiwan's society and economy. It needs insight and extensive analyses and investigations to look into its full scope. Based on the discussions and analyses above, the effects of social and economic impacts are outlined and discussed in this section, in order to provide a basis for further discussion :

4.1 Social Impacts

1) The social structure of hazard areas is facing the issues such as out-migrating population and changes of population structures. The progress of recovery also affects local communities.

Although the population has gradually moved back to the hazard areas, comparing to the initial stage after the Chi-Chi earthquake occurred, yet damages on physical environments, losses of employment opportunities, and fears on earthquake and other disasters will make the population in hazard and remote areas reducing considerably, and the population structure will be dominated by aged people. In addition, despite the facts that the hazard areas are mostly consisted of traditional farmers' villages that have better neighborhood relationships, as well as the efforts of social workers of post-disaster psychological healing on victims, that help the victims to face the reality of the destructions in the preliminary stage; however, owing to the slow progress in reconstruction, the pessimistic atmosphere has getting stronger. The progress in reconstruction will have a key effect in hazard areas.

2) The disaster and the recovery after this disaster have promoted the forming of community consciousness among community residents and the concerns of public affairs.

Although the hazard areas are mostly consisted of traditional farmers' villages that have better neighborhood relationships, yet the recent tasks of promoting community empowerment movement and forming of community consciousness in Taiwan had lower wills of participating and promoting in the hazard areas. Nevertheless, with the relationships of interdependent and assistance among the victims, as well as the participations of reconstruction plans, the victims of hazard areas should be able to raise their concerns in their communities and public affairs, and higher the opportunity of getting physical actions.

3) The disaster became a turning point for Taiwan's community empowerment movement in recent years, as well as a brand new start for the aborigine people and their cultures.

With the aggressive promotion on applying citizen participation and community empowering as the means of reconstruction the hazard areas, many enthusiastic young people with professional skills got into the hazard areas and helped the victims to reconstruct their communities. Because the huge differences between the hazard areas and the general communities, the workers of community empowerment movement have a chance to understand the variation of community empowerment and to obtain the opportunity of practicing. Besides, owing to the emphasis on the idea of "reconstruction starting from the community", aborigine people have a chance to review their own cultures and customs, as

well as to think able their future development. This will integrate their unique physical spaces, industries, and cultures into the great achievement of post-disaster reconstruction.

4) With participations of civil strengths in response and recovery tasks, Taiwan is aware the precious and importance of its civil strengths and civil organizations.

Many different types of civil organizations had quickly mobilized, devoted into the response and recovery actions, and donated significant amount of money after the Chi-Chi earthquake occurred. This had proved how strong Taiwan's civil strength is, and made Taiwan's society to further emphasize its civil strengths and civil organizations, as well as to think about the issues such as how to unify and utilize these resources more effectively. However, this kind of devotion has its unthinkable negative impacts, such as the non-profit organizations were unable to get sufficient donation after this earthquake, because many donation went to various earthquake recovery funds.

5) After the earthquake, the hazard and environmental issues had been emphasized to the public, and the crisis awareness also had been promoted.

Although many typhoons, severe thunderstorms, and smaller scale earthquakes had frequently happed in Taiwan, the extensive damages caused by Chi-Chi earthquake brought significant impact to Taiwan's society through the reports and images from the media and the experiences of participating rescuing tasks. In addition, following disasters such as landslides and debris-flows, and problems on reconstruction, gave the general population a chance to recognize the issues of environmental developments, hazards, and hazards prevention, as well as to enhance their crisis awareness that used to be very weak.

4.2 Economic Impact

1) No major impact on the global economic growth of Taiwan for 1999

The damage caused by Chi-Chi earthquake has induced severe economical and social impacts on the losses of the entire economic growth of Taiwan. Besides, the damage of industrial facilities and the electrical power shortage had caused a lower season economical growth rate in comparing to the predicted number. However due to the sustainability of the companies, the recovery of many industrial sectors were far better than they were expected. It turned out that the economical growth rate for 4th season of 1999 reached 6.77%, which was higher than the predicted number.[6] As a result, the average economic growth rate in Taiwan for year 1999 is 5.67%. This fact shows that Chi-Chi earthquake made no major impact on the total economic growth of Taiwan.

2) Chi-Chi earthquake has induced severe economical and social loss, the recovery funds will become a burden of the government

According to the statistics prepared by Directorate-General of Budget, Accounting and Statistic of Executive Yuan in October 1999, the total direct economical loss caused by Chi-Chi earthquake is about 10.7 billion US dollars. Although this number is lower than those of Kobe and Northridge earthquake, it would be different if we look at the ratio between the loss amount and GDP. The ratio in Taiwan is as high as 3.7% for Chi-Chi earthquake while is only 2.0% in Japan for Kobe earthquake and 0.7% in US for Northridge earthquake. In other words, Chi-Chi earthquake had caused a more severe economic impact to Taiwan than Kobe and Northridge earthquake done to Japan and US respectively. It had been calculated that the government had spend about 0.6 billion US dollars (20 billion NT dollars) in short term recovery and emergency response. Also the recovery fund needed was roughly estimated to be 5 billion US dollars (1670 NT dollars). This has a negative impact to Taiwan in recovering from the Asian Economic Storm. Further more, since the government has promised not to increase the tax rate to collecting the recovery fund, the government is facing a critical challenge.

3) Negative effects on the entire industry and certain regional industrial sectors

As described before, despite of some local businesses and small industries, the economic activities of the affected area are mostly dominated by agriculture. Thus the affected area is a sub-economic area of Taiwan and has lower economic productions. Chi-Chi earthquake not only had caused significant economic loss in the affected area, in addition, the large-scale landslide, debris flow, ground failure, and road damage had also cut off the agricultural production and transportation. This drags the economic activities of the affected area to an even worse situation. Also the earthquake has prevented the activities of tourist and results in a significant economic loss.

4) Means of livelihood for the people at the disaster area had been affected due to the damage to the regional industrial sectors and decline of economic activities

Since the earthquake had destroyed the agriculture and tourism industries of the affected area, many people had lost their jobs. In the mean time, the expected reconstruction of public facilities and houses has not yet begun plus the regional economic are not fully recovered. It becomes very difficult for people to find new jobs, even they are willing to transfer to different kinds of works. The situation is even server for the aboriginal people and farmers with higher age.

5. Issues and Possibilities of the Future

To synthesize all analyses and illustrations above, we can find that Chi-Chi earthquake has made many problems and tasks more clear, such as hazard mitigation and the development of country land. And, it also provides some directions for future development. There are the brief illustrations below.

5.1 Issues

1) Our hazard mitigation system is not completely structured and made into totally practice. It is worse especially in the township level system.

According to the practical response and rescue process, although the hazard mitigation system of Taiwan has its prototype, it can't run smoothly in the practical operation. There are many problems, especially in the township and community level organizations in the hazard areas. For example,

i、 It is sufficient in the experiences of making decisions, ordering, and compromising in the emergence response actions, but lacks in the useful S.O.P. and normal trainings.

ii、 The connecting and coordinating works can't be run smoothly between departments of governments.

iii、 It is necessary to strength the mechanism on the collecting news, delivering hazard information, and relative equipments.

iv、 Insufficient knowledge and special equipments in searching and rescuing victims.

v、 Others.

2) The internal level governing system is powerless (especially in the township), and the governing system can't be run smoothly.

Some emergence responses, like searching and rescuing, can't be operated practically. Besides the professional problems, there are some important factors on the insufficient manpower and governing power of the government's internal operations, and the bad interactions between different level governments.

3) The problems of land development and the characteristics of the environment, especially on some sensitive environment matters, are not being emphasized.

The strong vibration of Chi-Chi earthquake not only caused finance loss, the debris flow and collapse of mountain, it also destroyed the road system, villages and farms. Besides, similar damages often happen in every typhoon and heavy rain weather. The huge amount of money is used to fix the road systems and gives some relieves to people again and again, and

gives huge pressure on Country finance. Judging from these factors, we can find out that Taiwan's land development and use are all taken emphasizes on economical benefits, but ignored the necessary evaluations of the ecological environments.

4) Many buildings and public facilities were heavily damaged. It is necessary to raise the structure standard of bearing earthquake.

Many housings, schools and township halls suffered serious damages in this hazard. It not only caused huge amount of finance loss, many lives were also harmed. There must be problems existing in all sections, such as planning, designing, constructing, maintenance and managing. To control the standard of safety is the emergent tasks to solve the problems.

5.2 Possibilities of the Future

In addition to the issues stated above, there are also some things encouraging and worth to be thought about in response and rescue actions in the mitigation process of this earthquake. For example,

1) It appears that the military can provide helpful assistances in the rescue section and shows its importance in the mitigation and prevention of the hazard.

2) The grassroots of Taiwan show their huge power in these actions. However, it is necessary to have some efficiently coordinating actions between them and made them into integrated. After that, they could play key roles in the mitigations and rescues when disasters strike.

3) Although it caused huge damages and losses in Taiwan, Chi-Chi earthquake also provides Taiwan and other countries better fields and chances for earthquake relating researches and practical experiences. There is a prospect on the ways of making good use of these chances and also will broad out the viewpoints of academicals and practical experiences.

4) We have found that there is a systematic operating mechanism gradually formed among grassroots and communities. A good connection has to be made between this mechanism and internal governing system, and processing a necessary integration and revolution. It would be an important key factor to both the reconstruction of the hazard areas and Taiwan's modern, democratic social system.