BASIC ASSESSMENT OF VULNERABILITY BASED ON THE POLICIES OF THE MITIGATION PROGRAM FOR TYPHOON DISASTERS IN TAIWAN

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Vulnerability evaluation is an important part of disaster mitigation. It is known that vulnerability is variable with time in which losses are increased or decreased. However, it is not necessarily true that the policies upheld for mitigation has an overall effect of decrease in losses because it may result in a false sense of security in an exposed area. The purpose of the study is to present the policies and strategies of the mitigation program during 1958 to 2007 by the Taiwanese government and related disaster data from several severe typhoon disasters. The trend of the mitigation programs and the effects that these policies had to influence the losses are then analyzed based on those data and preliminary cost-benefit analysis. According to the result, we made a conclusion of the policies held on the development and mitigation.

keywords: *vulnerability, mitigation program, policy, typhoon disaster*

1. INTRODUCTION

Natural hazards are a hindrance to safety and productivity, often resulting in enormous disasters. In order to decrease losses from these disasters, governments implement engineering and non engineering solutions. For instance, the US Federal Emergency Management Agency (FEMA) is a systematic program upholding the procedures before, during, and after disasters. There are four main procedures from FEMA, centered on response, recovery, preparedness, and mitigation. The main purpose of the strategies and policies designed and held in these procedures is to prevent and/or to decrease any serious occurrence of loss. However, the occurrence of losses depends not only on the number of the policies implemented but also on the efficiency of these strategies are. Aside from these, loss is also affected by the natural/social conditions that the community or distribution of these elements in a hazardous area. However, the overall efficiency of a mitigation program has been treated only recently in related studies fields.

The importance of vulnerability therefore becomes a major concern in disaster mitigation. It has been found that factors that lead to disasters include not only destructive natural hazards but also vulnerability factors, such as environmental and social factors, and human activities. The definition adopted by the United Nations in the International Strategy for Disaster Reduction (ISDR)[1] is representative, which states that vulnerability is a set of conditions and processes resulting from physical, social, economical, and environmental factors that increase the susceptibility of a community to the impact of hazards. Several extended models introduced this definition. Wisner[2] mentioned that vulnerability is generated for economic, social and political processes. Turner[3] evaluated vulnerability from exposure, sensitivity, and resilience. Bohle[4] divided vulnerability into internal and external parts: internal part as being the ability to cope with the hazard; the external part as being the exposure to risk and shocks. Birkmann[5] explained vulnerability according to a five-layer concept, which we consider in this study. This definition adopts a core level and considers that vulnerability contains spheres with different objectives. Using this definition, the authors evaluated vulnerability based on the community and on the state (government) in a previous study[6].

Some previous methodologies have proposed indices for estimating vulnerability, such as GDP, urban growth, and deforestation rate[5]. These methodologies have shown vulnerability distribution in a specific area at one time or for a designated hazard. However, vulnerability changes not only with difference in space scale at one time scale, but also with different time periods at one location. The latter distribution is more relevant for us here in helping to understand how the mitigation strategies in Taiwan influence the decrease in the occurrence of flood related disasters. This applies since the probability that the occurrence of a loss is variable due to the interactions between the mitigation policies and the environmental and/or social conditions in a community. Therefore, during different time periods in one location, any trend of vulnerability in time can markedly express the interaction between governments, community, and the individual.

Before starting our vulnerability evaluation, we first look at the historical changes of the mitigation policies in Taiwan. Therefore, it is necessary to have a description of the mitigation program and the changing of governmental association from 1958 to 2007. We then proceed with the efficiency evaluation of the mitigation program based on cost-benefit analysis, which derives our conclusions and recommendations in this study.

2. TAIWAN'S POLICIES AND GOVERNMENT ASSOCIATIONS OF MITIGATION PROGRAMS

The central government leads the mitigation program designed in Taiwan. On the other hand, associations are tasked in central government and the three-level local governments, including city, town, and village counterparts, to implement the program. The changes of the mitigation program and government associations shown here are from 1958 to 2007. Three sub-periods are selected to interpret the differences in the programs: 1958 to 1982, 1982 to 1999, and 1999 to 2007.

(1) The first period from 1958 to 1982

During this period, the frequency of the disasters is quite low, according to the data from the National Fire Agency of Taiwan, averaging about 4.08 disasters per year, including flood, earthquake, typhoon, and other disasters. Most of them however, were typhoon disasters. On the other hand, losses in this period is high, exceeding five hundred people injured, dead, and disappeared every year.

When a disaster occurred, treatments for the mitigation were held by independent associations. In other words, during this period there were no specific government associations grouped and responsible for natural hazards.

(2) The second period from 1982 to 1999

In contrast to the first period, the frequency of disasters increased in this period, averaging 5.88 disasters per year. There were two severe disasters that occurred; one is a aircraft disaster in 1994, and the other is a sediment and flood disaster caused by a typhoon in 1996. Though the frequency of the disasters increased, the losses of infrastructure, and human life (dead, and disappeared) were decreased. The agricultural losses were also initially monitored from this period in 1990, when disasters that include natural and man-made costed a sum of USD 300Million.

From 1982 to 1994, the mitigation program was mainly focusing on engineering facilities to prevent and to maintain environmental conditions and to prevent disasters. The Natural Hazard Mitigation Manual of Taiwan was also established within this period. Data from this period indicate disasters were based on natural hazards alone. Taiwan's government started to consider the procedure to manage massive scale disasters in 1994, after a huge earthquake that occurred in Los Angeles and a tragic flight disaster in Nagoya. The Hazard Mitigation Program was established shortly after. This program was to deal with the strategies which should be taken after such disasters' occurrence. It was the first time that the Taiwanese government recognized the need to manage man-made disasters and formalized the necessary steps to take in such events.

(3) The second period from 1999 to 2007

A massive earthquake occurred at the beginning of this period in 1999. The number of dead and injured persons in this earthquake was estimated as 14,022 people. Some 105,553 structures were destroyed, and the losses in agriculture were also noted (although difficult to estimate). On the other hand, the earthquake caused many shallow and deep landslides in mountainous areas of Taiwan[7]. The landslides and accumulated sediment caused severe sediment disasters, including floods, debris flows, and landslides, after typhoon events throughout 2000 to 2004. Sediment disasters clearly caused increased losses during the period, especially the losses on human life and agriculture.

The 1999 earthquake revealed insufficiencies on the systematic and political level of the mitigation and served as a warning to the governmental

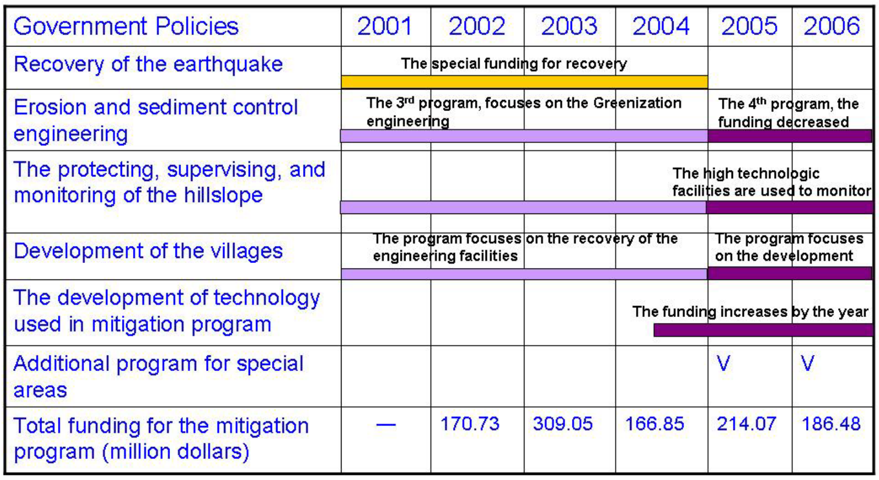

Figure 1 The trend of policies in the mitigation program during 2001 to 2006.

authorities. In order to improve the capability for mitigation, governments adopted the Disaster Prevention and Protection Act to replace the Hazard Mitigation Program in 2000. Moreover, an emergency mitigation system and enactment for crisis management were established formally for the first time. According to the Disaster Prevention and Protection Act, there are four levels from the central government to the local government that administer the work on mitigation when disasters occur.

At the same time, a National Science and Technology Program for Hazard Mitigation was established to prevent the disaster from occurring in the wake of the 1999 earthquake. Since typhoon and earthquake disasters are the most frequent threats to Taiwan, the program's main theme was divided into three parts: these include the program for typhoon disaster, the program for earthquake disaster, and the disaster prevention system. Along with this Program, a National Science and Technology Center for Disaster Reduction was established in 2003. The main work for this center involves organization and integration of resources of other involved government associations, research on mitigation technology, and assistance in the improvement of existing mitigation programs.

The main mitigation treatment for sediment disasters were designed and held by Soil and Water Conservation Bureau (SWCB), Fire Agency, and the local government. The SWCB is the main association to lead the mitigation into practice; the Fire Agency mainly leads to relieve the disaster victims. According to the policy manuals from 2001 to 2006 and other information from central government, adopted strategies can be divided into two sub-periods, from 1999 to 2004 and from 2004 to 2007. In the first sub-period, policies focus on the post-earthquake recovery, while the second sub-period focuses on the development.

From 1999 to 2004, policies for the sediment disasters could mainly be divided into six categories: engineering facilities for recovering from the earthquake, erosion and sediment control engineering, the protection, supervision, and monitoring of hillslopes, development of rural villages, the development of technologies used in mitigation program, and additional program for special areas (see Figure 1).

In the first sub-period, except for the engineering facilities and reforestation for recovery, local people were hired to attend to mitigation work which was also seen as an important policy to help the exposed area recovery. On the other hand, the mentioned erosion and sediment control, which is a long-term program started from 1982 is also a continuous program for three periods. Before 2004, the program simply focused on the erosion control in mountainous areas. A fourth program started in 2004 considers the basin and automated monitoring.

3. THE POLICIES AND THE LOSS DURING RECENT YEARS

(1) The emergency management procedure

To evaluate of vulnerability of the government policies, we considered the procedure of the emergency management with the policies held in recent 10 years. The emergency management procedure includes successive four stages, which are mitigation, preparedness, response, and recovery. According to these four stages in the emergency management procedure, we connect the strategies held before, during, and after a disaster occurs with these four stages as shown in Table 1. The "Mitigation" was determined as the tangible strategies in this study, because it contains engineering strategies, preparation, and supervision of the equipment. The "Preparedness" includes the strategies for designing and planning the

Table 1 The strategies in the emergency management procedure

Stage	Strategies	Description
Mitigation	1. Construction policies: The engineering strategies 2. Non-construction policies: Supervise the land-use, Basic equipment preparedness	Tangible strategies
Preparedness	1. Training and exercise 2. Establishment the mitigation system 3. Announcing system	Intangible strategies
Response	1. The cooperation and association of the emergency management center 2. The resource circumrotation 3. The resource coordination	Strategies and operations held when the disasters occur
Recovery	1. The short-term recovery 2. The long-term recovery 3. The collection and use of the funding	Strategies held during or after disasters occur in order to recover the destroyed part

mitigation resources or collecting the data for announcing or forecasting. These are thus considered here as intangible strategies. The "Recovery" is the set of strategies held for recovering a destroyed area during or after disasters, including the recovery of the lifeline, roadway, and engineering facilities. The "Response" is the set of operations conducted when a disaster occurs. This study does not deal with "Response" since we assume that the cost for the response does not include in the emergency management procedure.

(2) The cost and benefit analysis of the mitigation program

To estimate the cost and benefit of the mitigation program, it is first necessary to clarify the relationships between the strategies of the mitigation program. In effect, we proceed according to a basic cost-benefit analysis to show how the government is willing to pay for the mitigation program. Ko and ChenThe relationship is shown in Eq. (1), (Ko, 2004),

$$L_{be}P_{be} - L_{af}P_{af} \geq C \qquad (1)$$

where L_{be} and L_{af} are the loss occurs before and after the mitigation program, respectively; P_{be} and P_{af} are the probability of the natural hazard before and after the mitigation program; C is the cost for the mitigation program.

In this study, we assume that the probabilities of the occurrence of each disaster are the same, because of the engineering facilities were designed by the standard of 200-year return period. Consequently, P_{be} and P_{af}. result 0.05. From the Eq. (1), we can get a relationship among the decrease of the loss (L_{be} - L_{af}), the cost for the mitigation (C), and the disaster probability (P), which is shown in Eq. (2) as below:

$$P(L_{be} - L_{af}) \geq C \qquad (2)$$

From Eq. (2), the minimum cost that the government is willing to pay for the mitigation program equals to the product of the probability and the decrease of the losses. It also means that the benefit of the mitigation program is calculated according to the reduction of the losses decreased between two disasters. It is also the ratio of C and P, which means that the acceptable losses after the disaster can be estimated when we have the data of C, P, and L_{be}.

On the other hand, we also consider that several events occur between two disasters, including loss, recovery, mitigation, and preparedness (shown in Figure 2). Since we assume that no severe disasters occur before the first disaster, it is understood that no strategies or policies were applied for decreasing the risk of the natural hazards. Based on this assumption, we see two important points. First, there are no loss, recovery, mitigation, and preparedness variables in Eq. (1) before the first disaster. Second, the cost for the emergency program could be calculated according to the function of the C and the ratio of P and L. The cost for the first emergency program is the product of probability and losses that occurred after the first disaster.

Based on Figure 2, the relationship between loss (L), recovery (R), mitigation (Mi), preparedness (P), and cost for the mitigation program (C) is shown here as Eq. (3),

$$Mi + P = C + L + R \qquad (3)$$

On one hand, the purpose of the emergency programs are to recover the environmental and social conditions after a disaster occurred and on the other hand increase the ability to cope with the threat of natural hazards. Therefore, the sum of the mitigation and preparedness should be equal to the sum of the money paid for the emergency program,

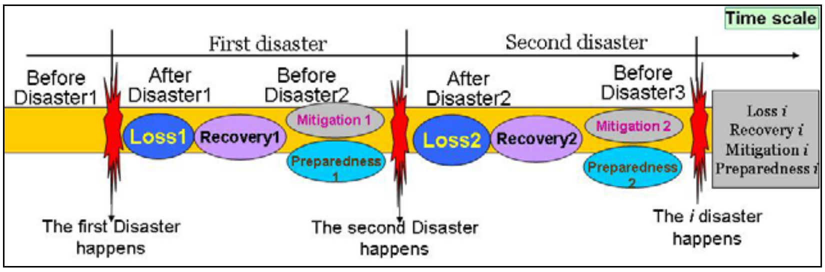

Figure 2 The relationship of items in mitigation program between several disasters

Table 2 The relationship of items in mitigation program between several disasters

Year	Human Losses (number of persons)				Buildings collapsed			Agricultural Loss (million dollars)	Total Loss (million dollars)
	Dead	Disappeared	Injured	Total	Complete	Half	Total		
1990	75	18	41	134	187	323	510	221	840221
1991	6	8	24	38	50	160	210	-	-
1992	8	6	15	29	13	4	17	141	81141
1993	3	1	6	10	0	50	50	390	12390
1994	71	20	178	269	206	350	556	289	891289
1995	10	26	30	66	20	33	53	712	168712
1996	56	22	475	553	505	802	1307	600	1749600
1997	70	7	129	206	123	43	166	149	600149
1998	42	16	58	116	32	207	239	385	270385
1999	2418	35	11569	14022	51722	53831	105553	230	162525230
2000	93	33	232	358	434	1725	2159	319	1680319
2001	225	129	588	942	646	1978	2624	179	3000179
2002	10	1	281	292	6	0	6	35	51035
2003	6	1	20	27	0	0	0	128	21128
2004	60	34	525	619	376	151	527	213	1410213
2005	42	8	152	202	0	0	0	627	150627

the loss in the disaster, and the money paid for recovery.

The sum of the mitigation and preparedness is thus considered here as the coping capacity which anticipates decreasing vulnerability. Therefore, the calculation describes how much losses were decreased in proportion to the resources put to mitigation.

4. RESULT AND DISCUSSION

(1) The losses and funding for the mitigation data

According to the funding data during 1990 and 2005, the funding for mitigation program was increased every year, especially after the earthquake occurred in 1999. The losses data includes agricultural loss, construction collapsed, and human injured, dead, and disappeared. Vulnerability is thus shown by the amount of losses each year, which is evaluated by how much government payment is received. Human loss here only considers of the dead and disappeared. The amount of this loss was calculated as USD 3000 per person, which is the price that government pays for each person. The infrastructure loss was calculated by considering buildings that partially and completely collapsed. The price that government paid for the half collapsed buildings equal to the half price of those that completely collapsed, which is USD 1500 per building.

(2) The initial result of the vulnerability evaluation

By using to the previously described method, three typhoon events were chosen to evaluate the efficiency and losses with results shown in Table 3. The three typhoons were selected mainly on account of similarity in affected area and the type of resulting disasters caused. The differences of the losses are USD 207 and 446 million dollars. After the first disaster, USD 1,634 million was paid for mitigation and preparedness. Therefore, appears that the efficiency of these policies after the first disaster was estimated as USD 207 million. We then considered the second disaster causing USD 615 million dollars paid for prevention of the next disaster, resulting in USD 446 million. Based on

Table 3 Cost-benefit analysis results during three typhoon disasters

Typhoon Events	Herb	Toraji	Mindulle
Year	1996	2001	2004
Loss (million dollars)	760	553	107
The cost of the mitigation program (million dollars)	3.8	1.0	2.2
Recovery (million dollars)	870	60	179
Mitigation / Preparedness	1,634	615	288

this method, we can simply interpret efficiency between the two typhoon disasters using the historical data. However, this method did not consider the continuity in policy and other losses, which we will show in a future study.

5. CONCLUSIONS

The political and systematical changing of the mitigation program in Taiwan was shown in detail in this study. Following this program, the basic concept of cost-benefit analysis, and vulnerability framework, the vulnerability at the government level was evaluated using cost-benefit analysis. Here we made some conclusions drawn as follows:

(1) According to the data, the political associations for the mitigation enacted by Taiwan were improved in the recent 10 years, especially after the impact of the earthquake that occurred in 1999. The Disaster Prevention and Protection Act in 2000 was the first act which clearly mentioned the necessary steps and actions when a disaster occurred. Before 1999, there was also some improvement in the work of disaster prevention. However, it mainly followed after severe disasters.

(2) According to the policies held for the sediment disasters, we use the loss to represent vulnerability, the money paid for mitigation, and preparedness to represent the coping capacity. A basic cost-benefit analysis was considered to evaluate the efficiency of the government policies. Based on the concept and the relationship between these items and the emergency management procedure, it is easy to show the amount of the money spent for mitigation and preparedness.

(3) Based on the mentioned cost-benefit analysis, the money paid for one disaster was estimated as USD 1,634 million which resulted in an efficiency of USD 207 million. In a second disaster, the money spent was USD 615 million which had an efficiency of USD 446 million.

(4) The study describes the cost and benefit of the mitigation policies implemented in Taiwan. In the past there was also related study interpreting the changing of the mitigation policies in recent year and the comparison of the mitigation policies held in different countries. In this study, we consulted and extended these studies and used a simple concept to quantify the efficiency of the part policies in the mitigation programs. The results show that the efficiency can be evaluated according to the funding and the loss data after natural hazards occur.

Based on present findings, we wish to expand this study from its current simplicity in evaluation to clarify development and mitigation.

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