CHINESE EXPERIENCE WITH POST-NATURAL-DISASTER RECONSTRUCTION

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Abstract

The paper begins with a discussion of the facts about natural disasters with emphasis on both floods and earthquakes that happened in China, and then shifting the focus from the lessons to be learnt from reconstruction to improvement of reconstruction strategies following a natural disaster. This includes policy development, decision making technology, and evaluation models and etc. The paper concludes with a summary of reconstruction experiences learned from the practices in past decades in China.

Post-Natural-Disaster; reconstruction; China

INTRODUCTION

At the beginning of a millennium, it is appropriate but also necessary to look back upon the events happened in China and to see what lessons and prognoses concerning post-natural-disaster reconstruction can be derived from them for the future.

The Government of People's Republic of China, in response to various natural disasters that occurred in the country after its founding in 1949, particularly the 1976 Tangshan Earthquake which caused 242,000 deaths and the 1991 Anhui and Jiangsu flood which caused 5,000 deaths and 77.9 billion RMB of direct economic losses, noted the importance of significantly improved reconstruction strategies.

Reconstruction following a natural disaster is a complicated problem concerning social, economical, cultural, environmental, psychological, and technological aspects. However, for developing countries or regions, it is a good opportunity to change its original economy development model and to push the urban and rural renewal forward. Therefore, improved strategies and reconstruction plans are the key to accelerate the reconstruction process and to improve human settlement environment.

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FACTS ABOUT NATURAL DISASTERS IN CHINA

China is exposed to almost every type of natural hazard as shown in Figure 1. The great natural catastrophes that happened in the last 50 years in China are:

1. 1954 middle reaches of Yangze River great floods, more than 30,000 people died;
2. 1959-1961 continual great droughts caused large scale famine and disaster area of 153,346 km^2 in average;
3. 1975 Henan Province heavy rainstorm caused 26,000 deaths;
4. 1976 Great Tangshan Earthquake caused 242,000 deaths;
5. 1987 Daxinganling Mountain forest fire caused 80 million cubic meter wood loss;
6. 1991 Anhui and Jiangsu Province big flood caused 5,000 deaths and 77.9 billion RMB of direct economic losses;
7. 1998 big flood in Yangze, Songhuajiang and Nen river basin caused collapse of more than 6 million rooms and direct economic losses of 200 billion RMB.

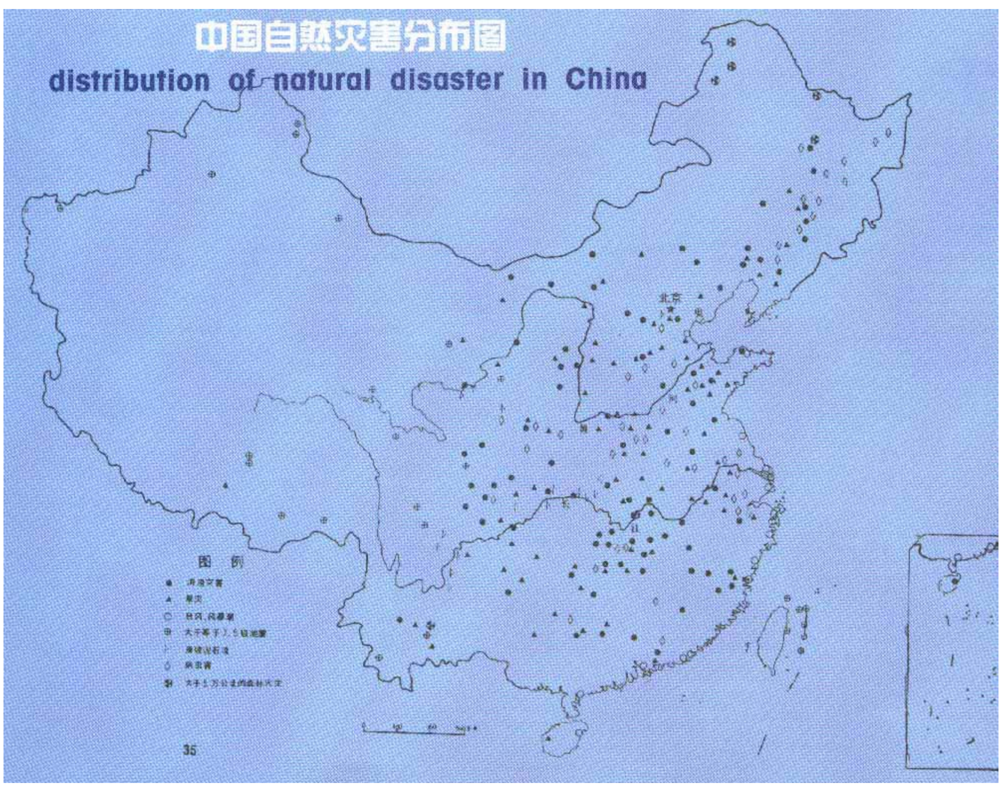


Figure 1: Distribution of natural disasters in China

China’s natural disasters can be classified into the following seven types based on their characteristics, management and mitigation system. The most important disasters are shown in Table 1.

1. Flood and waterlogging
2. Earthquake
3. Meteorological disaster, including drought, rain waterlogging, rainstorm, tropical cyclone (typhoon, hurricane), cold wave, damage to plants caused by a sudden drop in temperature, freeze injury, windstorm, hail, snowstorm, tornado and thunderstorm etc.
4. Geological disaster, including avalanche, landslide, mud-rock flow, ground rupture, collapse, volcanic eruption, freezing and thawing, ground settling, land desertification, soil and water loss, and salinization etc.
5. Ocean disaster, including wind-driven tide, tsunami, sea wave, sea ice, seawater intrusion, red tide, tide disaster, positive movement, and seawater encroachment etc.
6. Crops disaster, including crops and plant diseases and insect pests, plague of rats, agricultural meteorological disaster and agricultural environment disaster etc.
7. Forest disaster, including forest plant diseases and insect pests, plague of rats and forest fire etc.

Table 1: Disaster types in China

Major	Minor
Drought	Landslide
Flood	Mud-rock flow
arthquake	Pests
Hails	Forest fire
Freezing spells	Snow storm
Typhoon	Sand storm
	Cave breakdown
	Red tide

The frequency of natural disasters and direct economic losses caused by natural disasters in the last five decades in China are shown in Figures 2 and 3 respectively.

Great natural catastrophes are classed as “great” if the capacity of the region to help itself is distinctly overtaxed, making interregional/national assistance necessary. This is usually the case when more then 1000 people are dead.

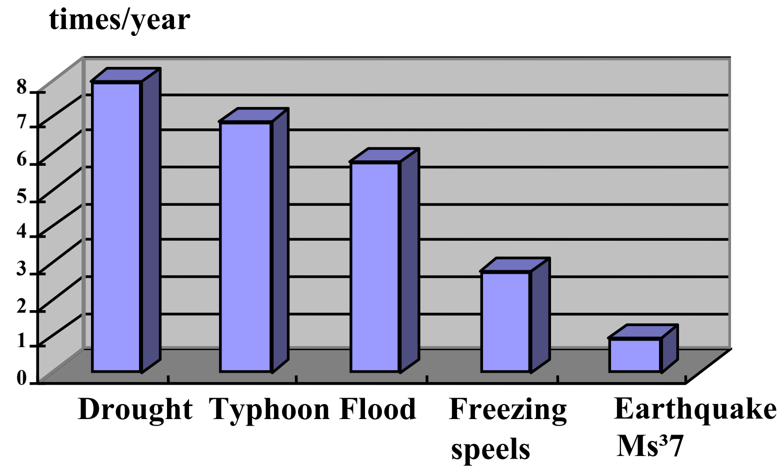


Figure 2: Frequency of natural disasters in 1949-2000 in China

The concerns engendered by great natural catastrophes caused by earthquakes and floods are described below.

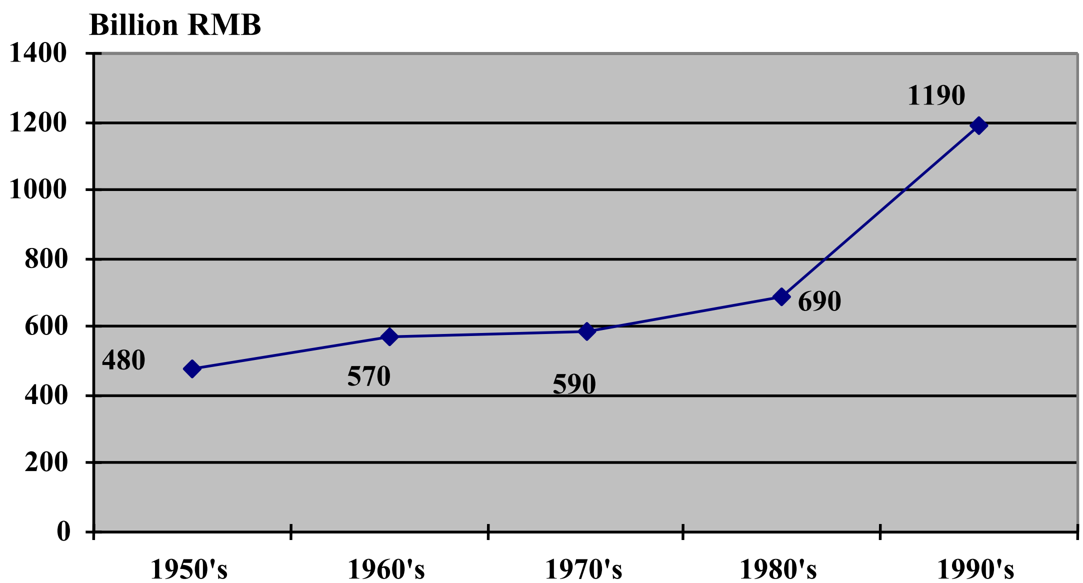


Figure 3: Direct economic losses caused by natural disasters in 1950-1999 in China (Converted into 1990 prices)

Earthquake disasters

Damaging earthquakes have occurred in almost every province of the country. About one half of China's population lives in earthquake-prone areas with a seismic intensity of VII and above, which covers 3,120,000 square kilometers and consists of 32.5% of the total territory. Earthquakes in China in 1950-1999 have resulted in at least 281,706 deaths and have caused the damage of 20,223,989 rooms and the direct economic losses of 107.627 billion RMB.

The great earthquake catastrophes 1950-1999 in China are shown in Table 2. It follows that the great majority of earthquake losses are come from these eight great catastrophes. The number of deaths, number of damaged rooms and direct economic losses of these eight great earthquake catastrophes amount to 98%, 66% and 84% of that of the total in 1950-1999 in China respectively.

Table 2: Great earthquake catastrophes 1950-1999 in China (More than 1000 people are killed)

	Time of Occurren-ce	Location	Mag-nitu-de	Number of death	Number of damaged building rooms	Direct Econom. losses Million RMB
1	Aug 15, 1950	Chayu, Tibet	8.6	2486	4500	5
2	Mar 22, 1966	Xingtai, Hebei	7.2	8064	5080000	2103
3	Jan 5, 1970	Tonghai, Yunana	7.8	15621	338456	644
4	Feb 6, 1973	Luhuo, Sichuang	7.6	2199	66024	195
5	May 11, 1974	Zhaotong Yunnan	7.2	1541	66000	193
6	Feb 4, 1975	Haicheng, Liaoning	7.4	1328	74739	1733
7	Jul 28, 1976	Tangshan Hebei	7.8	242769	7679800	28316
8	Sep 21, 1999	Nantou Taiwan	7.3	2295	116379	57610
Total for 8 great catastrophes (a)				276303	13425898	90799
Total for catastrophes 1950-1999 (b)				281706	20223989	107627
A/b(%)				98	66	84

The building damage, and direct economic losses caused by earthquakes 1950-1999 are shown in Figures 4 and 5 respectively. They indicate that in the last five decades:

- The direct economic losses are increasing decade by decade in general, especially the last decade of the last century.
- The number of rooms damaged is decreasing in the last two decades, but it is still increasing in the 1990s compared with that of in 1980s.
- Reduction of the economic losses should be considered as a priority.

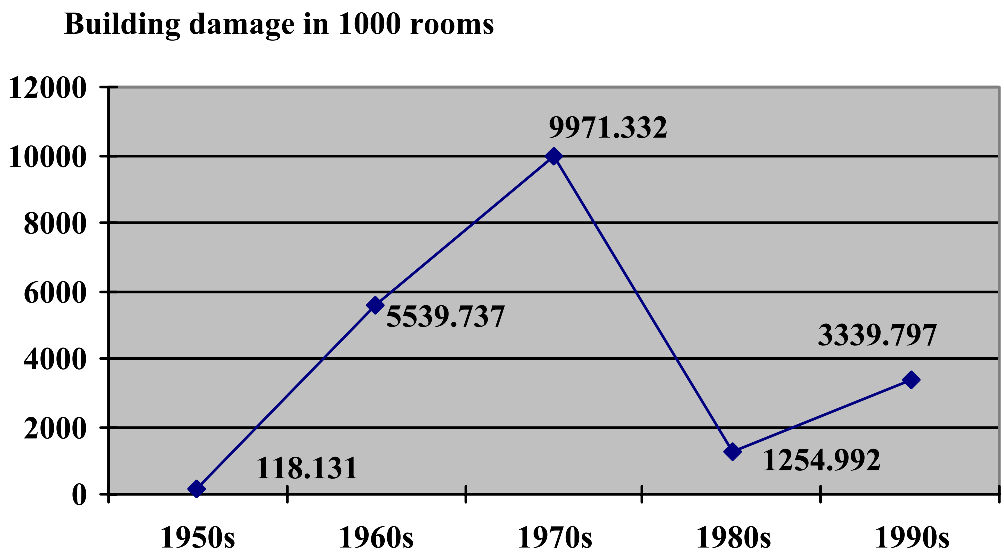


Figure 4: Building damage caused by earthquakes 1950-1999 in China

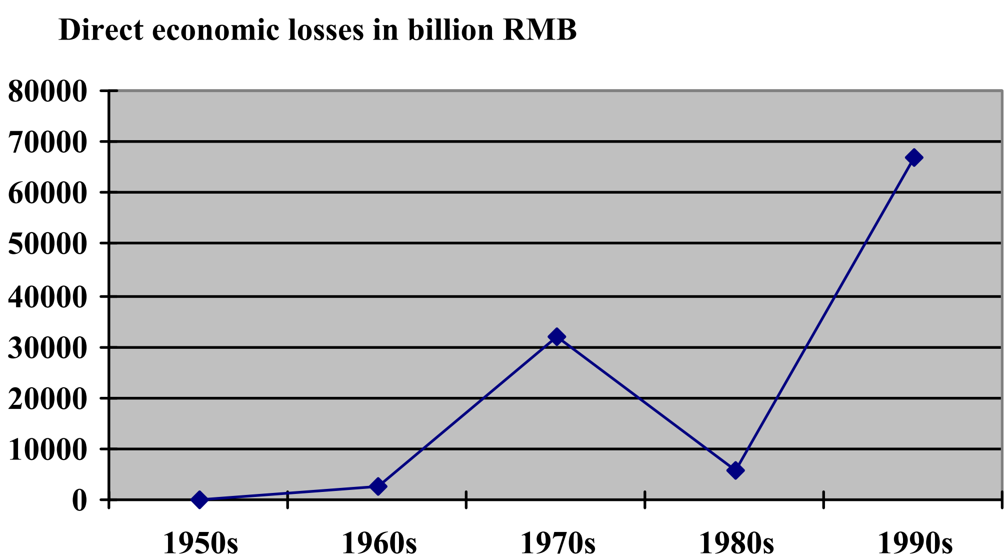


Figure 5: Direct economic losses 1950-1999 in China

Flood disasters

According to the statistical data, in the last five decades in main land China:

- Annual flood disaster-affected areas and consequent disaster areas amount to 7,804,000 km^2 and 4,308,000 km^2 respectively;
- Average rate of negative consequences of disasters reached 55.2%;
- In average, 1.9 million rooms collapsed every year;
- In average, 5,500 people died annually.

The disaster area caused by floods (1950s-1990s) in China is shown in Figure 6. The figure shows that the disaster area caused by floods in the decades of 1950s to 1990s is increasing, especially the decade of 1990s.

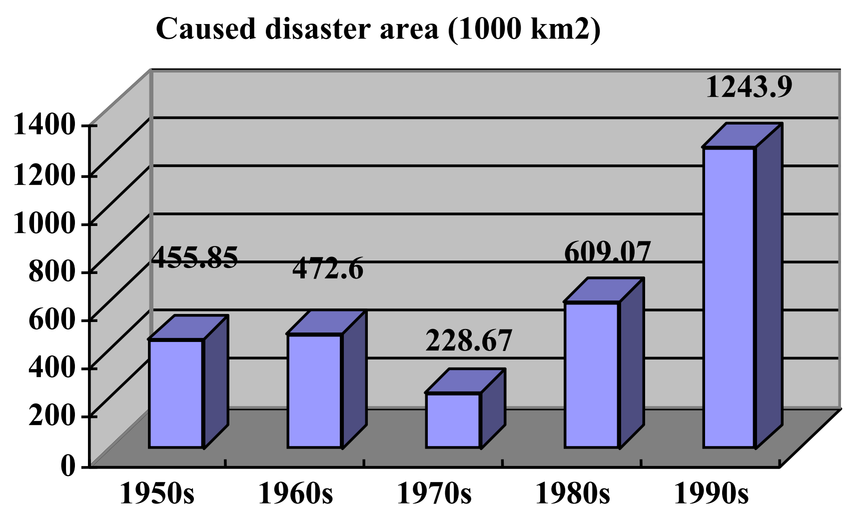


Figure 6: Caused disaster area by floods 1950s-1990s in main land China

The direct economic losses caused by floods 1991-1998 in main land China are shown in Figure 7. It indicates that they are increasing in general.

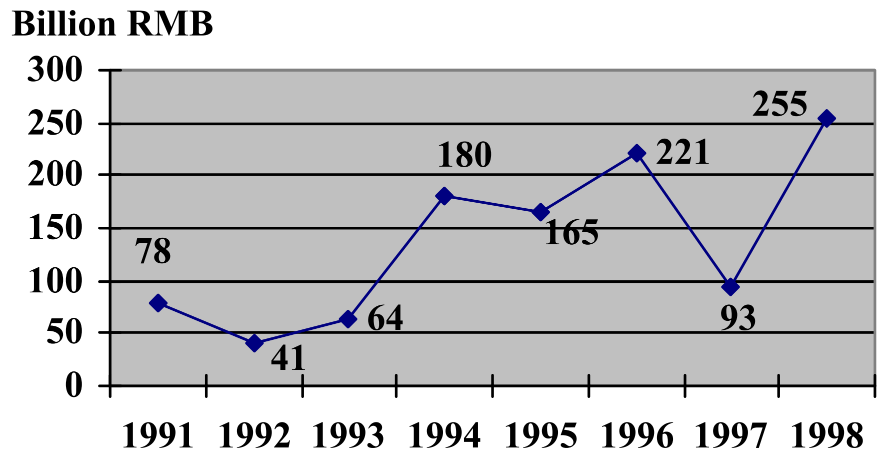


Figure 7: Direct economic losses caused by flood in main land China

Figure 8 shows the number of deaths caused by floods 1950s-1980s in the main land of China is decreasing. However, about 50,000 people died by floods every decade.

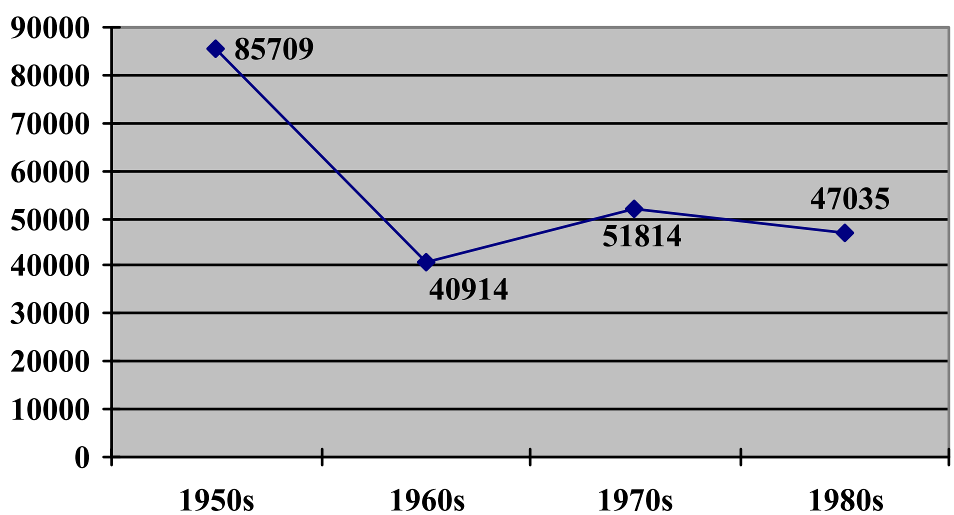


Figure 8: Number of deaths caused by floods 1950s-1980s in Main land China

RECONSTRUCTION LESSONS

Shelter Safety following 1975 Haicheng earthquake

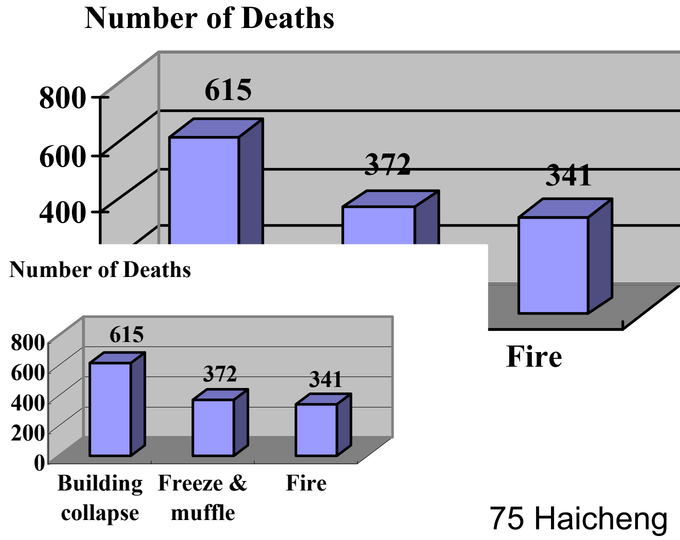
Evacuation and logistics problems happened in the relief phase of the 1975 Haicheng earthquake; it is an unwise example for disaster risk management integration. The total number of deaths caused by the earthquake was 615. However, an additional 713 died after the quake, caused by freeze, asphyxiation and fire as shown in Table 3 and Figure 9.

Jingjiang Retention basin development

Floods in China's Yangze River used to inundate many thousands of square kilometers almost every year, claiming the lives of thousands of people. The retention basins are effectively used to direct the excessive flow over the designed flood areas. At the beginning of 1950s, comprehensive flood control measures were taken as a result. These included the construction of dikes along the river to combat overflowing and the creation of flood diversion areas, which are normally called retention basins that are inundated during floods in order to reduce the discharge in the river. Jingjiang is the largest one of these basins and was built in 1952. It has an area of 920 square kilometers and can take 6.2 billion cubic meters of water.

Table 3: Casualties caused by 1975 Haicheng Earthquake

Cause	Number of Deaths	Number of Injuries
Building collapse	615	9422
Freeze & asphy	372	6578
Fire	341	980
Total	1328	16980



F 75 Haicheng Earthquake

During 1954, a great flood of 100-years frequency occurred in the Yangtze River, the maximum inflow above the Jingjiang section was 71,900m^3/sec, while the safe discharging capacity in this section was only 45,000m3/sec. Thus the inflow sluice of Jingjiang Diversion Basin was operated three times to ensure the safety of the Jingjiang Dike and Shashi city located downstream from the Diversion basin. This prevented about 30,000 of fatalities.

Development and Settlement of retention basins on Yangze River is an unwise example of development in an exposed area. Now it would be impossible to inundate this area because almost a million people have since settled here. This means that the towns and cities located downstream like Wuhan are even more exposed than they were in 1954.

Sediment deposition and decrease of flood diversion and flood storage capacity – lessons learned from 1998 great flood

During the 1998 great flood in the Yangtze River, flood-peak stage was much higher than the maximum of what had happened previously, although the peak flow did not reach its historical maximum. The main reasons were as below.

- The wetted cross-section in Yangtze River was greatly reduced due to sediment desposition ; and
- The flood diversion and flood storage capacity of the lakes along the river banks were greatly decreased. The total areas of the lakes connected with the middle and downstream reaches of the Yangtze river were 17,198 km2 in 1950s. In 1980s, however, only 6,605 km2 were left. That means it decreased by 61.5%. More than 30 billion m3 of the volume of the lakes were lost.

Reconstruction following the 1976 Tangshan Earthquake

The new Tangshan city was divided into three districts, namely the old district, the eastern coal mining district, and the Fengrun new district. They are separated by a distance of 25 km and form a triangle. Old district was rebuilt at the site of the former Lubei district. The eastern coal mining district was built at its original place. The organizations, enterprises and inhabitants of former Lunan district were relocated to Fengrun county town and rebuilt a new district there. Many troubles happened with relocation, such as: people were not willing to relocate due to lack of good schools, hospitals and difficulties in getting jobs for their spouses.

Lack of housing for young couples was found after the completion of reconstruction which took about 10 years, because the potential households were not considered in the beginning of reconstruction and reconstruction plan in Tangshan city.

During the quake, 600,000 people (86% of the city's total urban population of 700,000) were buried in the ruins. Among them 22% were rescued from danger by themselves and 58% were rescued by local residents and troops stationed at Tangshan city. Therefore, local self-rescue is most important and should be well organized. The mixing of young and aged people may, in fact, be the best way for earthquake disaster mitigation.

Some of the debris, including bricks, wiring and plumbing, was recycled and re-used in the reconstruction process. Although recycling bricks by hand is a slow and labor-intensive form of recycling, it can save debris transportation and tipping costs and also save valuable resources. At the same time, it can help immediate local job generation and solve clean-up problems.

Principles for Reconstruction Plan

Post-natural disaster reconstruction is not only a good opportunity to transform the destructed area into a sustainable community, but also an opportune moment to prepare for the next disaster. Of course, there would be no disaster when an earthquake or a flood occurred in an area without human beings and human activities. Therefore, natural disaster is not only a natural phenomenon but also a social event.

We used to analyse the consequences caused by a natural disaster on the basis of natural science and technology in the past. Now we have to consider the social impact of a disaster and take additional actions on the basis of social sciences. The following principles should be considered in making reconstruction plans based on the above mentioned concepts.

- Integrating strategies of disaster mitigation with those of social, economic and environmental development

- Paying attention to the partnership with emphasis on the participation of not only government officials and technical experts but also sociologists, psychologists, legal experts and the disaster victims.
- Setting priorities for infrastructure reconstruction and provision of services based on cost-benefit analyses, social equality, and environment quality.
- All of the buildings to be reconstructed should not only meet the requirements of natural disaster resistance but also pay attention to follow local habits and customs and to keep local tradition and style.
- Making the widest possible use of local materials and reuse of the materials and elements from damaged buildings.
- Considering local design and construction skills in natural disaster reduction.
- Developing training program with emphasis on implementation of the reconstruction plan

Reconstruction Following Flood Disaster

A great flood disaster normally spreads to a large area. For example, the affected area and consequent disaster areas were 212,000 km2 and 130,667 km2 for the 1998 great flood disaster respectively. A huge number of villages and towns are located in these areas. Therefore the reconstruction plan should be made elaborately.

Relocation

Strict formalities should be followed in making decisions about relocation of the villages and towns. Giving priority to the original site should be considered in any reconstruction plan, because the foundations of buildings can be reused and some of the infrastructures are probably still functional.

When relocation is needed for villages and towns, the following requirements should be considered in selection of the new site.
- With higher ground elevation and smooth terrain.
- With stable subsoil and its bearing capacity is high enough.
- Arrangement of drainage system is easy.
- Keep away from the areas near the mainstream of the flood water and with concentration of floating debris.
- Prohibiting making construction at the site nearby the assigned flood-diversion sluices.

Life safety measures

In order to ensure life safety, the following measures are taken in flood-prone areas especially in retention basins.
- Building encircling dikes for affected villages and towns when it is possible.
- Establishing refuge areas at places at relatively higher levels. Houses can be built in these areas in normal times.

- Establishing temporary shelter platforms, which must be filled up with large amount of soil and can be used to build schools and restaurants, etc.
- Building multistory houses and public buildings with flat roofs.
- Planting trees around houses.

Rebuild at the original place

The reconstruction plan should be made with consideration of
- Protection of cultivated land
- Rational land use
- Promotion of the development balance among rural areas, and
- Sustainable development requirements.
- Unified implementation should be considered.

Land use adjustment

Regulating the land use is necessary during the reconstruction phase, such as:
- Avoiding reconstruction at the site with high risk of flood disaster.
- The flood-prone flatlands should be used as parks and farmlands instead of construction sites.
- Prohibiting the area with steep slopes from development.
- Critical facilities should not be distributed at places with high risk of flood caused by the collapse of dykes and dams.
- Decreasing population density in flood-prone areas.
- Making regulations for land use.
- Demolishing the buildings that block the flow of water.
- Multistory buildings with flat roofs are encouraged.
- The scattered village and township enterprises should be rebuilt at the same places but with integration.

Flood Resistant Buildings and Structures

Raising flood resistant capacity of buildings and structures mainly means increase of their capacity to resist hydrodynamic force and soakage. Some critical measures are listed below.

- Making plan for upgrading and renewal of existing buildings and structures in order to raise their flood resistance.
- Developing design codes for flood resistant buildings and structures in order to make them have adequate loading capacity to resist hydrostatic, hydrodynamic, and buoyant forces; solid and stable structural system; reliable connection; and better integration.
- Establishing flood hazard zoning and land use planning to guide the development in flood-prone areas.
- Adopting structural system with flat roof and fewer corners in plan.

- Foundation of buildings should have a bed course made of "Sanhetu" (a mixture of lime, clay, and sand to which water is added) with broken stone or crushed brick. The embedded depth of the foundation should no less than 50cm and it should be built by rubble or brick with cement mortar.
- Adopting water soakage resistant building materials.
- Lime or cement should be added in case of using earthen products, such as adobe. Otherwise the exterior surface of earthen masonry should be coated with waterproof materials.
- The impact force from sampans should be considered in building design.
- The exits should be placed at a level more than one meter higher than the floor level.
- Countermeasures should be taken for underground facilities to avoid inundation.

RECONSTRUCTION STRATEGY

Policy Development

The main objectives of disaster reduction are to reduce: (1) Deaths and injuries; (2) Property losses; (3) Impact on economic and social development; and (4) Damage to environment through: (1) Completion of a set of disaster reduction projects which are critical for national economic and social development; (2) Application of scientific and technological achievements in disaster reduction; (3) Public awareness; and (4) Improvement of institutional and operational mechanism of disaster reduction.

Flood disaster

- Prevention is more important than response. In case of extraordinary floods, it is absolutely necessary to strive for avoiding serious dike-breaches by taking provisional measures, aiming to reduce the extent of the damage.
- Both economic and social benefits should be considered in evaluating flood control projects, since flood prevention works make a contribution to public welfare.
- Developing overall planning for river basins to coordinate with other users in water resources development and to achieve optimum results of disaster prevention and derivation of benefits.
- Combining use of structural and non-structural flood control measures to the match national economy.
- Paying greater attention to management and maintenance, and establishing a responsibility system for flood works.
- Establishing administrative and command system to strengthen the day-to-day work of river management and the centralized leadership of the government for making a prompt decision in case of an emergency.
- Public awareness, informed rescue and public participation.

- Giving equal importance both to flood control works in the lower reaches and to soil conservation in the middle and upper reaches of the rivers because flood disaster prevention can never achieve enduring success without continuous efforts in soil conservation.

Earthquake disaster

- Working out an "Integrated Disaster Reduction Plan" at national, provincial and county levels and bring the plans into line with the related economic and social development plan;
- Buildings and structures should met the disaster resistant requirements through design codes and upgrading;
- Raising disaster resistant capacity of infrastructures and life line systems;
- Improving disaster reduction legal systems and
- Improving disaster monitoring and information systems.

Relocation criteria for rural area can be described as follows.

1. 90% of the housing and public buildings should be eligible for reconstruction;
2. The villagers concerned must be in full agreement to move to the new site;
3. The proposed site should be close to the villagers' fields, and should have convenient access to water supply, power and telecommunications;
4. The proposed site must be geologically safe and free of environmental hazards;
5. The relocation costs should be financially feasible including allowance for land requisition, three years' agricultural production losses, and removal of the families and their goods.

Decision Making Technology

The history of earthquake disasters repeatedly exhorted us to be careful enough in the following two pressures faced immediately after a natural disaster.

- Economical, social, psychological and political pressures foster rehabilitation and reconstruction as rapidly as possible. The prevailing attitude is a desire to help those who have suffered injuries, disruption of their lives and property damage. The overriding concern is with immediate needs, not with future disasters.
- The recent bitter experience and the concern for significant reduction in future risk foster improving safety in post-earthquake reconstruction. The survivors hope to build and to repair buildings and structures to withstand shaking from future earthquakes much better.

The correct and rational decision making for post-earthquake reconstruction including land-use planning, emergency shelter construction, priority of recovery of economic sectors and financial resources for reconstruction, provides the key to solve the above mentioned pressures.

System dynamics method

It can be applied to analyse the complicated socio-economic system by computer simulation. In the phase of reconstruction, a system dynamics model is suitable for solving the following four important and complicated problems:

- Population recovery and growth
- Infrastructure system reconstruction
- Housing and other building construction, and
- Priority for rehabilitation and development of industrial sectors

The following steps were taken to establish the system dynamics model:

1. Problem Identification, including identifying the problem to be solved and its requirements, determining the main variable, and collecting relevant data and analyzing the relationship among different factors and variables;
2. Making causality feedback drawings and setting up a model framework, including determining modules for the model, or the submodels and their modules; making a causality feedback return circuit diagram;
3. Making system flow charts, using system dynamics symbols;
4. Setting up DYNAMO equations, compiling a system program by using DYNAMO language and testing on the computer; and
5. Drawing up possible solutions for decision making and doing simulation test on computer, analyzing results for different solutions and proposing recommendations for decision makers.

In case of industry development, the simulation test for investment and real estate growth of different industrial sectors in Tangshan city after the earthquake was conducted on the computer by the proposed model. The results have shown that the output value and real estate value given by the computer simulation test are close to the practical values.

Analytical hierarchy process method

It can be used to solve very complicated problems which are difficult to deal with fully by quantitative analysis. The method consists of the following steps:

1. Problem Identification

Dividing the factors involved in the problem to be solved into several hierarchies and indicating the relationship among the factors. For example, for the decision making problem, the top hierarchy represents objectives; the middle hierarchy represents links to reach the objectives, such as tactics, restriction and criterion etc.; the lowest hierarchy represents the policy and measure to solve the problem.

2. Structuring judgment matrix

3. Arrange in importance order for the hierarchy. For an element at one level higher in the hierarchy, a weight W_i (arranging in importance order for the element in the present hierarchy and related to it) can be calculated by the following formula:

$$B\,W = \lambda \max W$$

Where B is a judgment matrix, and W is weight value of the order of importance.
4. General Arrange in importance order for hierarchy
5. Checking consistency
When the ratio between random consistency index and consistency index for the general hierarchy arranged in importance order is less than or equals 0.10, it can be recognized as satisfactory consistency.

The hierarchy analysis model is established based on the following four principles:
- Give priority to that which is closely related to people's life;
- Give priority to that which is closely related to national and regional economy development projects;
- Give priority to local key enterprises, and
- Postpone or cancel the construction of projects with less benefit and with unreasonable distribution of industry

According to the responses of leaders and experts from Tangshan Municipal government, the analytical hierarchy process method after a damaging earthquake indicates that:
- Rehabilitation and reconstruction of the infrastructure, such as water supply, power supply, communication etc., should be put in place in the first place;
- More attention should be paid to the job generation and housing construction; and
- Attention should be paid to recovery of most effective industrial sectors.

“Three cuts” strengthening strategy

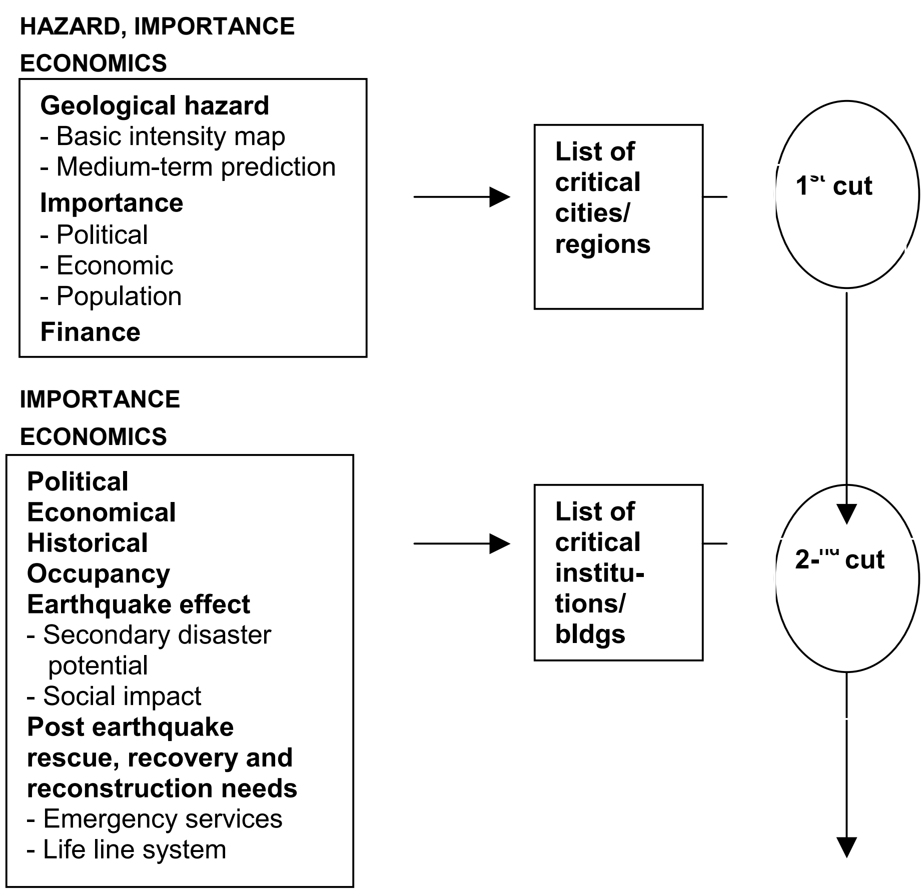
The “three cuts” process was used to identify the buildings and structures needed to be strengthened following the 1976 Tangshan earthquake, based on the limit budget as shown in Figure 10. First cut was to identify critical cities or regions where strengthening existing buildings is urgently needed. The second cut was to identify critical institutions in the identified critical cities for which function loss due to an earthquake will cause heavy life and/or proporty losses. The third cut was to identify critical buildings/structures in the identified critical institutions, for which damage or collapse will cause serious loss of life and/or property losses. Then effective and economic strengthening procedures could be, and were followed.

Evaluation Models

Post-earthquake activity model is an effective tool for evaluation of the result of the activities following a damaging earthquake. Through the model, the activities are divided into the following phases:

1. Emergency Phase. Emergency measures are usually those taken immediately following disaster impact and are mainly directed towards saving life and protecting property, and to dealing with the immediate disruption, damage and other effects caused by the disaster. The phase applies to a fairly short period ranging from several days to 2-3 weeks after impact. The end of the phase is characterized by completion of the following activities:

- Search and rescue
- Provision of emergency food, shelter and medical assistance etc.
- Clearance of ruins on the main roads



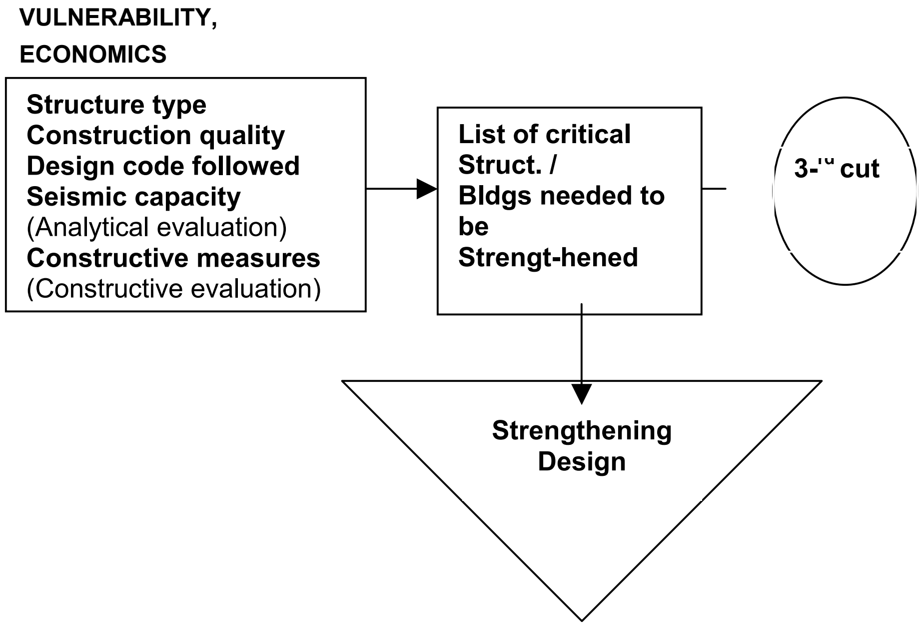


Figure 10: “Three cuts” process

2. Recovery Phase

Recovery phase is the process by which the impacted areas are assisted in returning to their normal level of functioning following a disaster. The recovery process can be protracted, taking several months, or even more than one year. The following three main categories of activity are usually regarded as coming within the phase:

- Restoration of essential services, such as the main urban services, public utilities, traffic and transportation etc., and of repairable buildings and structures ;
- Provision of temporary housing and taking measures to assist the physical and psychological rehabilitation of the victims of disaster;
- Basically clearance of ruins caused by the disaster

3. Recovery Reconstruction Phase (Reconstruction Phase I)

During this segment, the effected areas are assisted in returning to their level of functioning prior to disaster impact. Long-term measures of reconstruction, including the replacement of buildings and infrastructures which have been destroyed by the disaster are taken in the segment.

4. Development Reconstruction Phase (Reconstruction Phase II)

In the modern world, countries are becoming increasingly inter-related and interdependent. Therefore, the development reconstruction phase provides the link between disaster-related activities and regional or national development. Since the results of disasters are effectively reflected in future policies and the interests of regional or national progress, the following activities should be taken in this segment in order to produce the best possible benefits and to ensure that regional or national development does not create further disaster problems, nor exacerbate existing ones:

- Introducing improved and advanced building systems and programs;
- Applying experiences learned from the disaster in future research and development programs ;
- Utilizing international assistance to optimum effect

A typical post-earthquake reconstruction model is shown in Figure 11. Usually, for the first three phases, the duration of the latter phase is ten imes more than that of the former.

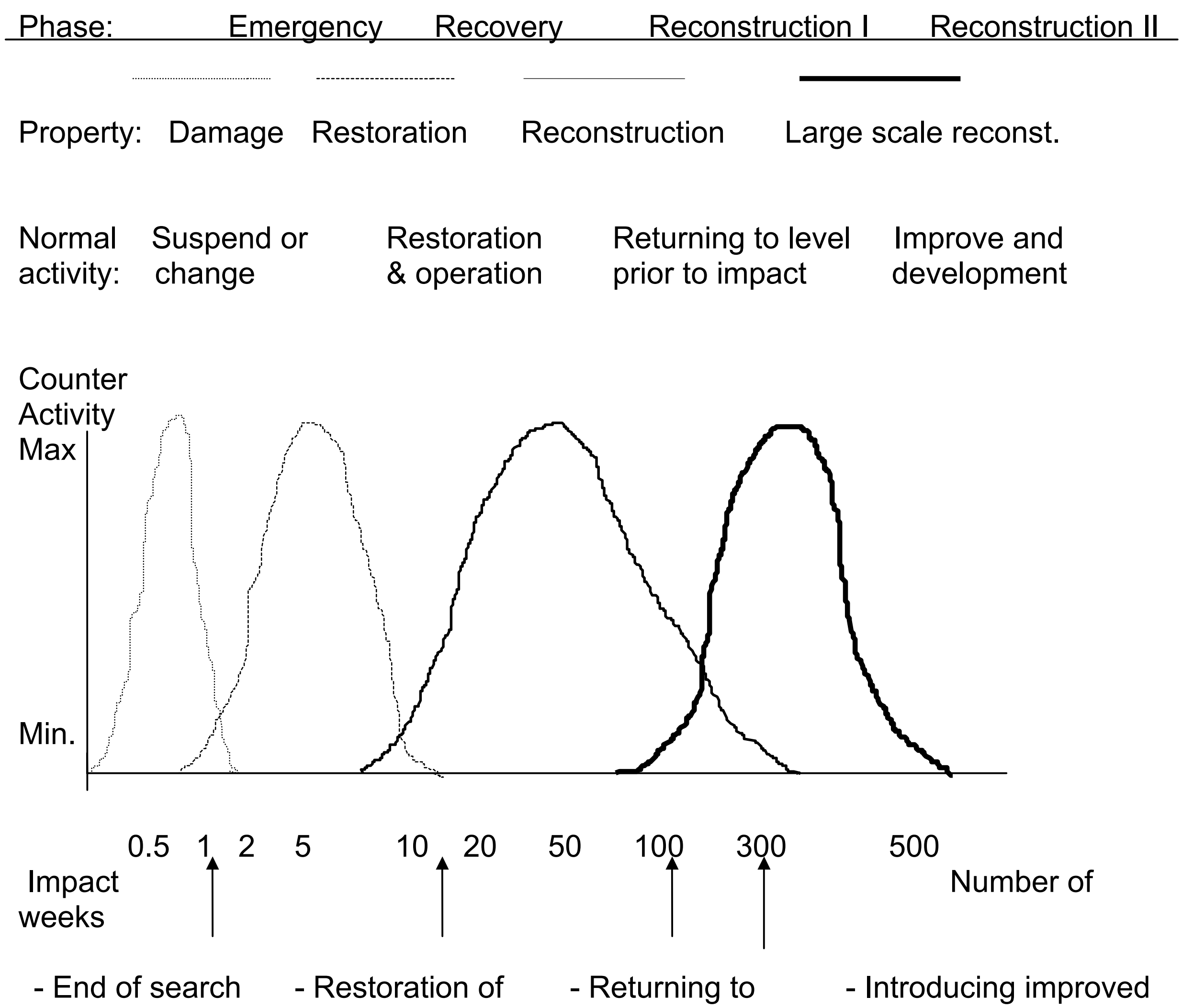
RECONSTRUCTION EXPERIENCES

According to the disaster reduction practices in China in recent decades, some useful experience for urban disaster management and planning are described as follows.

1. Reconstruction following a natural disaster is a complicated problem concerning social, economical and technological aspects. However, for underdeveloped countries or regions, it is a good opportunity to change its original economic development model, to push the urban and rural renewal forward. Therefore, rational decision making is the key to accelerate the reconstruction process and to improve the human settlement environment.
2. There are three choices for land use planning of post-natural-disaster reconstruction. Rebuild at the original place should be put in the first priority. Otherwise, partially rebuild at the original place, partially move to close neighboring placse may be considered. Renounce the original place and move to a new place is a more expensive and more difficult solution. It can be adopted on the following conditions:
   - It is very difficult to take measures to mitigate the future disasters;
   - Inhabitants are willing to relocate; and
   - It is economically feasible.
3. It is necessary to identify priorities for recovery of economic sectors because financial resources are limited. The system dynamics method, analytical hierarchy process method, and “three cuts” process can all be used for this purpose.
4. Post-earthquake reconstruction activity consists of four phases: Emergency, Recovery, Reconstruction I, and Reconstruction II. A post-earthquake reconstruction model based on these phases is an effective tool to evaluate the results of reconstruction activity and the effect of policy decisions.
5. Disasters can be substantially reduced through disaster management and implementation of disaster reduction plan. The most effective measures for disaster mitigation are:
   - Land use control and improvement of city planning;
   - Strengthening existing hazardous buildings and critical structures and facilities;
   - Improving design and construction techniques and practices through design codes and standards;

- Prediction techniques and warning system;
- Public awareness, education and training;
- Sound preparedness plans; and
- Sound reconstruction planning.

6. The important role of re-use of debris and waste management following a natural disaster are usually neglected or underestimated. Although some of recycled bricks were used in reconstruction process in China, it was in very small scale and mainly by hand.
7. To strengthen existing buildings, one has to start with consideration of increasing the earthquake resistant capacity of whole buildings, and one should never just strengthen the damaged items or even only strengthen the building without a comprehensive analysis.
8. International cooperation is necessary for mutual learning from limited experiences because natural disasters occur infrequently in any one country.



and rescue - Provision of emergency food, shelter and medical assistance - Clearance of ruins on the main roads	essential services and repairable buildings and structures - Provision of temporary housing - Clearance of ruins	level of functioning prior to disaster - Replacement of buildings and infra-structures	and advanced building systems and programs - Applying experiences learned from the disaster in future research and development programs - Utilising international assistance to optimum effect

Figure 11: Typical Post-earthquake Reconstructiion Activity Model

REFERENCES

Ye, Yaoxian and Norio Okada. (2001). "Improving Management of Urban Earthquake disaster Risks" *Earthquake Engineering Frontiers in the New Millennium, Edited by B.F.Spencer, Jr and Y.X.Hu*, A.A.Balkema, the Netherlands, pp.113-118.

Lou, Puli. (1986). "Planning and Management for the Prevention and Mitigation of Flood Disasters in China" *Planning for Crisis Relief, Towards Comprehensive Resource Management and Planning for Natural Disaster Prevention,* UNCRD, Vol. 1, pp.1-27.

Ye, Yaoxian and Teizo Fujiwara. (1998)**.** "Post-Earthquake Conflict for Urban Aseismic Planning Comparing the 1976 Tangshan earthquake and the 1995 Hyogoken-Nanbu earthquake", *Proceedings of the 10th Earthquake Engineering Symposium,* Vol.3, pp.3581-3586, Japan

Ye, Yaoxian. (1986). "Earthquake Damage to Brick Buildings and Their strengthening Techniques", *Proceedings of the 10th Triennial Congress of the CIB, Vol.4,* pp.1583-1589, Paris

Ye, Yaoxian. (2001)**.** "Some Comments on EQTAP Master Plan", *Third Multi-lateral Workshop on Development of Earthquake and Tsunami Disaster Mitigation Technologies and their Integration for the Asia-Pacific Region,* No.11, EDM, Japan

Department of Finance and Administration, Ministry of Civil Affairs of China. (2001). *China Civil Affairs Statistical Yearbook,* China Statistics Press (in Chinese)

Ministry of Civil Affairs of P. R. China. (2001). *Natural Disaster and Disaster Relief in China*

Department of Monitoring and Prediction, China Seismology Bureau. (2001). *Corpus of Loss Assessment for Earthquake Disaster in Mainland China (1996-2000),* Seismology Press (in Chinese)

Liu, Shukun, Chief Editor. (2000). *Manual for Flood and Drought Disasters Control in China,* China Social Press (in Chinese)

EERI. (2000). *Financial Management of Earthquake Risk,* EERI Endowment Fund White Paper

Seismological Bureau of Hebei Province. (2000). *Record on Earthquake Disaster Relief Decision Making in Tangshan,* Seismology Press (in Chinese)

Hong, Yuqing. (1999). *Yangzi River: Flood Prevention and 1998 Great Flood Disaster,* China Water Conservancy and Power Press (in Chinese)

Jin, Lei, et al. Editors.(1999). *China: Strategy of safety and Calamity Alleviation in the 21st Century,* Henan University Press (in Chinese)

Berz, Gerhard, editor. (1999). *Topics 2000, Natural Catastrophes – The Current Position,* Munich Re Group

State Flood and Drought Control Headquarter Office and Institute of Hydrometric and water Resources of Ministry of water Conservancy. (1997). *Flood and Drought Disasters in China,* Water Conservancy and Power Press (in Chinese)

Zhou, Qijia and et al., Chief Editors. (1997). *Research on Social Recovery and Social issues in Tangshan Earthquake Disaster Area,* Seismology Press (in Chinese)

Takahashi, Tamotsu. (1996). Flooding and Sedimentation Disasters as Phenomena influenced by Human Activities, *Proceedings of Workshop on Disasters caused by Floods and Geomorphological Changes and Their Mitigations* (WDFGM)

UNDRO. (1991). Mitigating Natural Disasters*, A Manual for Policy Makers and Planners,* UN

China Seismology Bureau and State statistics Bureau. (1996). *Corpus of Loss Assessment for Earthquake Disaster in Mainland China (1990-1995),* Seismology Press (in Chinese)

State Statistics Bureau and Ministry of Civil Affairs. (1996). *Report of the Damage Caused by Disaster in China,* China Statistics Press (in Chinese)

Zhao, Mingji and Wen Qiuliang. (1995). *Practice and seek on flood Control Foundation,* China Water Conservancy and Power Press (in Chinese)

Kreimer, Alcira and Mohan Munasinghe. (1991).. *Managing Natural Disasters and the Environment,* The World Bank

Ye, Yaoxian. (1991). Contemporary Disaster Prevention Levels and Disaster Mitigation Methdologies, *Disaster Reduction in China,* Vol.1, No.2 Aug. 1991 (in Chinese)

Gu, Zebgjian and Chen Xinglian, Chief Editors. (1991). *Urban Earthquake Disaster Countermeasures,* Seismology Press (in Chinese)

Zou, Qijia et al. (1990). *Socioeconomic Impacts of the Tangshan Earthquake,* Academic Books and Periodicals Press (in Chinese)

Ye, Yaoxian. (1986). Planning and Management for the Prevention and Mitigation of Earthquake Disasters in China, *Planning for Crisis Relief, Towards Comprehensive Resource Management and Planning for Natural Disaster Prevention,* Vol.2, UNCRD

Ye, Yaoxian. (1980). Damage to Lifeline and other Urban Vital Facilities from the Tangshan, China earthquake of July 28, 1976, *Proceedings of 7WCEE,* Istanbul, Turkey.