

## INTEGRATED RELIEF AND RECONSTRUCTION MANAGEMENT FOLLOWING A NATURAL DISASTER

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### Abstract

Relief and reconstruction following a natural disaster are complicated problems concerning social, economical, environmental, psychological, and technological aspects. However, for developing countries or regions it is a good opportunity to change its original economy development model, to push the urban and rural renewal forward. Therefore, integrated management including improved strategy is the key to accelerate relief and reconstruction processes and to improve human settlement environment.

Based on the lessons learned from 1976 Tangshan, China and 1995 Hyogoken-Nanbu, Japan earthquakes, the paper begins with a discussion of importance of integrated management based on the facts of natural disasters with emphasis on earthquake disasters, and then the relief and reconstruction lessons learned from the disasters, including informed self rescue, temporary shelter, land use in reconstruction planning, housing reconstruction projects, and economy recovery are summarized. Improvement of reconstruction strategies following a natural disaster, including policy development, decision making technology, and evaluation models for reconstruction process are followed. The paper concludes with a summary of relief and reconstruction experiences learned from the practices in the past decades.

**Keywords:** *Integrated management, Natural disaster, Relief, Reconstruction.*

### Introduction

China is exposed to almost every type of natural hazard, especially floods and earthquakes. Within the period of January 1 to June 25, 2002, several floods and water loggings happened in the main land of China. The affected population reached to 110 million, 596 people died, 590,000 building rooms were collapsed, 1.67 million building rooms were damaged, 7.3 million hectares of crops area were affected, caused disaster area for crops were 3.86 million hectares, 880,000 hectares of crops were totally failed, the direct economic losses attained to 26 billion RMB.

The Tangshan and 1995 Hyogoken-Nanbu earthquakes caused extreme damage to a variety of structures and systems in Tangshan and Kobe and surrounding areas. There is an urgent need for research to understand the major causes of disasters and to develop methodologies to respond to problems encountered in the recovery efforts as well as to prepare for a similar natural disaster in a large urban area, especially in a mega-city in the future.

### Importance of Integrated Natural Disaster Management

Natural disaster is a natural phenomenon as common understood, however, it is also technological, economic, societal and environmental issues. Figure 1 shows a view of sustainable community as four concentric circles: the technology exists within economy, and both the technology and the economy exist within the society, and the three of technology, economy and society exist within the environment. As the

figure illustrates, all technologies require support from economy and society, all parts of the economy require interaction among people, all our requirements including air, food, water, energy and materials come from the environment and the environment surrounds society. Therefore, after a natural disaster, the disaster mitigation measures in the aspects of technology, economy, sociology and environment should be integrated in order to rebuild a sustainable community.

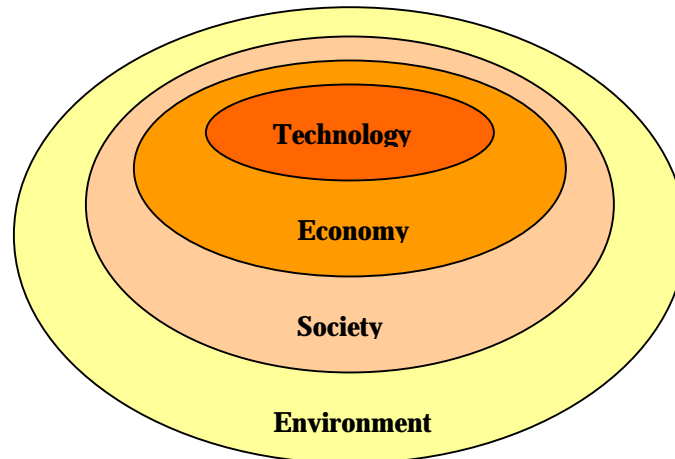


Fig.1 Sustainable community

The risk of natural disasters occurring in mega-cities is growing. There are now about 450 cities worldwide with a population of more than 1 million inhabitants. About 50% of the world's largest cities are situated along major earthquake belts or tropical cyclone tracks; and the average number of victims is 150 times larger during disasters than in the developed world, and the economic loss, as a percent of GNP, is 20 times greater. Large-scale catastrophes from urban disasters have been graphically and tragically demonstrated in recent years. Earthquakes of 1976 Tangshan, China, 1995 Kobe, Japan and 1999 Izmit, Turkey are all the virtual facts.

Table 1 shows the comparison of the disasters happened in 1976 Tangshan, China and 1995 Hyogoken-Nanbu, Japan earthquakes. Both earthquakes struck in the pre-dawn hours, both ruptured beneath urban areas with dense population, and both caused catastrophic damage. In Tangshan there were many more deaths dwarfed those in Hyogoken-Nanbu, however, in Hyogoken-Nanbu there were many more financial losses dwarfed those in Tangshan, and the amount of destroyed building stock and infrastructure was similar in both Tangshan and Hyogoken-Nanbu.

Both Tangshan and Hyogoken-Nanbu earthquakes are terribly striking examples of what earthquakes can do to a modern industrialized society. The loss of lives and the hardships of residents are tragic. The vast majority of deaths in Hyogoken-Nanbu occurred in the collapse of housing built by traditional Japanese technologies based on post-and-beam method with little lateral resistance and using thick mud and heavy tile for roofing. The vast majority of deaths in Tangshan occurred in the collapse of traditional Chinese housing with brick masonry wall and reinforced concrete slab and without consideration of earthquake requirements. However, there are relatively few new lessons to be learned from both Tangshan and Hyogoken-Nanbu earthquakes from an engineering viewpoint. The real lesson is that we have to motivate our societies to replace or strengthen deficient structures and systems, and to improve our planning and preparedness through integrated disaster management.

We did our utmost to mitigate natural disasters, especially in the last decade through IDNDR's activities. However, both of the number of disasters and economic losses caused by natural disasters in the last five decades in the world are still increasing (Figure 2). The same situation happened in China (Figure 3). Based on the analysis of past natural disasters, may be the integrated disaster management is the effective way to mitigate natural disasters in the future.

Table 1 Comparison of the disasters of the 1976 Tangshan and 1995 Hyogoken-Nanbu earthquakes

Item	1976 tangshan earthquake	1995 Hyogoken-Nanbu earthquake
<b>Parameter</b>		
Local time of occurrence	3:42am, July 28, 1976	5:46am, January 17, 1995
Location of epicenter	29°24'N 118°06'E Near Tangshan city, Hebei province	34°36'N 135°02'E Under the Akashi Straight, North of Awaji
Magnitude	7.8	7.2
Focal depth	12-16km	17km
Peak intensity	XI (China's Scale) VI-VII (JMA's Scale)	VII (JMA's Scale) XI-XII (China's Scale)
Ground motion	No record in epicenter area	Max. horizontal acceleration 817cm/s <sup>2</sup> Max. horizontal velocity 150cm/s
<b>Societal impact</b>		
Number of death	242,769	6,308 + 2 (not identified)
Number of injured	164,051	43,177
Survivors with Hardships of shelter	800,000	300,000
<b>Economic impact</b>		
Number of building collapse	<ul style="list-style-type: none"> <li>● Collapsed 3,219,186 rooms (non-engineered in country side and without consideration of earthquake requirements in Tangshan city)</li> </ul>	<ul style="list-style-type: none"> <li>● Fully collapsed 100,302 buildings</li> <li>● Partially collapsed 108,741 buildings</li> <li>● Damaged 227,373 buildings (Base shear coefficient 0.2)</li> </ul>
Economic losses	10 billion RMB Yuan (1976) \$5 billion USD (1976)	10 trillion Japanese Yen (1995) \$100 billion USD (1995)
Business interruption and loss of production	Regional economy is being extremely affected by temporary business interruption.	Regional economy is being severely affected by temporary business interruption and the loss of import/export capabilities.
<b>Environmental impact</b>	<ul style="list-style-type: none"> <li>● Ground failure (landslides, cracks in the earth's surface, and soil dislocation)</li> <li>● Pollution</li> <li>● Landscape failure</li> <li>● Building rubbish</li> <li>● Destructive area is located in ellipse area with 7,270 km<sup>2</sup> of Tangshan and Tianjin city.</li> </ul>	<ul style="list-style-type: none"> <li>● Ground failure (landslides, cracks in the earth's surface, and soil dislocation)</li> <li>● Pollution</li> <li>● Landscape failure</li> <li>● Building rubbish</li> <li>● Destructive area is located along the coastline of the Inland area with 5km by 20km parallel to the Port of Kobe.</li> </ul>
<b>Disaster characteristics</b>	<ul style="list-style-type: none"> <li>● The worst earthquake disaster since the 1556 Huaxian, Shanxi, Earthquake.</li> <li>● The first experience of urban earthquake disaster in China's history.</li> <li>● No big fire happened thanks to the rain following the earthquake.</li> <li>● The economic loss is the largest ever caused by a natural disaster in China.</li> </ul>	<ul style="list-style-type: none"> <li>● The worst earthquake disaster since the 1923 Great Kanto Earthquake.</li> <li>● The second experience of urban earthquake disaster in Japan since 1948 Fukui earthquake.</li> <li>● Conflagration following the earthquake.</li> <li>● The economic loss may be the largest ever caused by a natural disaster in modern times.</li> </ul>

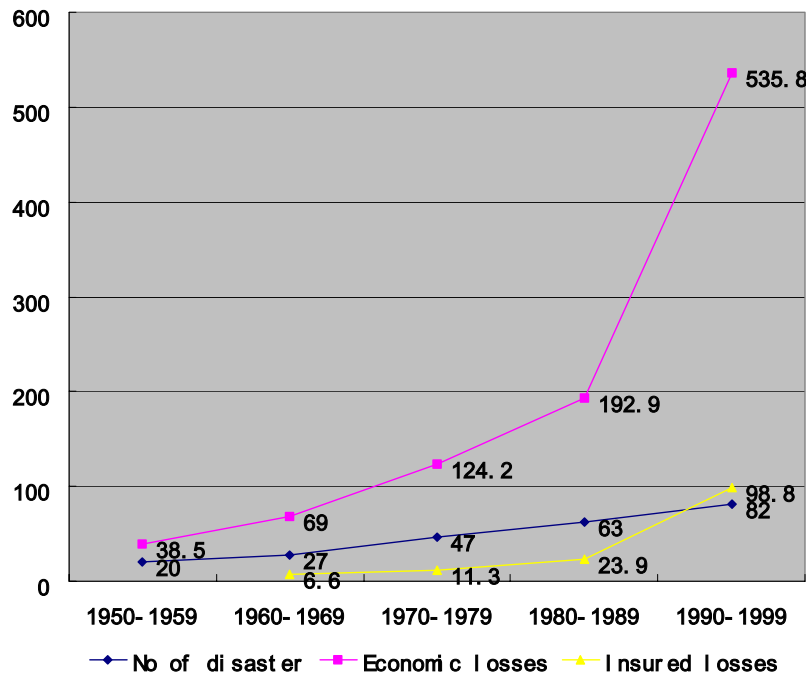


Figure 2 Number of disasters and losses in the last five decades around the world (Losses in US\$ bn , 1998 value)

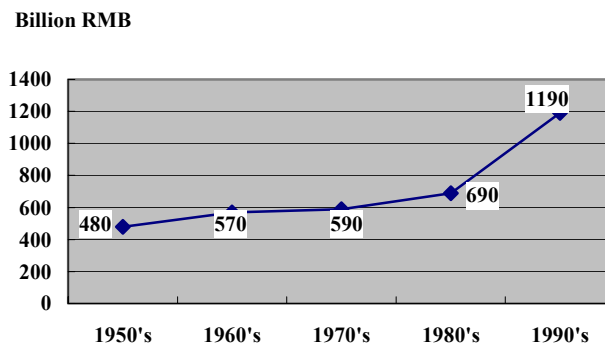


Fig.3 Direct economic losses caused by natural disasters in 1950-1999 in China (Converted into 1990 price)

### Relief and Reconstruction Lessons

#### Relief Bill in Japan

After the 1995 Hyogoken-Nanbu earthquake, quite a few volunteers from the country gathered in Kobe to participate in the rescue activity. Though the amount many people including foreigners donated to the victims reached about 180 billion yen (1.5 billion USD), only 400,000 yen per household was paid. Zenrosai as a cooperative insurer formed a National Congress to for a national security scheme for relief from natural disasters in July 1996. Within the next six months an astonishing 25 million signatures were collected from the public and 43,000 organizations as well. Thanks to the Japan Consumers' Co-operative

Union (JCCU), National Congress, prefectural Congresses, Lawmakers, National Council of Prefectural Governors and Diet Member's Council for Defending Japan against in earthquake, the bill was passed by the Diet at May 15th, 1998. Under the legislation, from April 1999, up to JPY 1 million (USD 7,600) as public aid will be provided to the victims of natural disasters in Japan, including earthquakes and floods. Zenrosai plans to make efforts to raise the maximum up to JPY 5 million or more and to strengthen as well as the solidarity mutual help network on a voluntary basis. Grass-roots action by organizations, such as Zenrosai and JCCU, has been helping people achieve their need for government assistance.

### **Informed self rescue in Tangshan**

During the 1976 Tangshan earthquake, 600,000 people that consist of 86% of the city's total urban population of 700,000 were covered by the ruins of the collapsed buildings. Among them 22% rescued from danger by themselves and 58% were rescued by local residents and troops stationed at Tangshan city. That means 80% of the covered people were extracted by the people lived in local community. Therefore, local self-rescue is most important and should be well organized. The informed self rescue and mixed staying of young and aged people are the best way for earthquake disaster mitigation.

### **Life safety measures in flood areas**

In order to ensure life safety, the following measures are taken in flood-prone areas especially in detention basins in China.

- Building encircling dikes for affected villages and towns when it is possible.
- Establishing refuge areas at places with relatively higher level. 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.

### **Temporary shelter**

Evacuation and logistics problem happened in the relief phase of the 1975 Haicheng earthquake is an unwise example for disaster risk management integration. The earthquake occurred in the severe winter. Most of the temporary shelters in affected area were made of wood elements and rice straw and there were no any heating devices. The total number of deaths caused by the earthquake was 615. However, the additional 713 were died after the quake and caused by freeze, stifling and fire. Therefore, temporary shelter should be safe and adequate for living.

The temporary shelters will be demolished while permanent houses are built, although they are urgent needs right after a disaster. Tangshan and Kobe experiences clearly show that: it is very difficult to find enough open spaces for temporary shelters and needs large scale labor to construct and needs utilities to support. Therefore, we have to consider how to reduce number of temporary shelters as much as possible. The possible ways are: Retrofitting damaged houses immediately after a disaster; Developing building systems which can be built phase by phase, the first phase completed building can be used as the temporary shelter. For example, building skeleton as the first phase completed building made of brick masonry or reinforced concrete was used as temporary shelter in Anhui Province after 1991 flood disaster in China.

### **Land use adjustment for flood in China**

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 site.
- Prohibiting the area with steep slope from development.

- Critical facilities should not be distributed at the place with high risk of flood caused by the collapse of dykes and dams.
- Decreasing population density in flood-prone areas.
- Making regulation for land use.
- Demolishing the buildings that block the water flow.
- Multistory buildings with flat roofs are encouraged.
- The scattered village and township enterprises should be rebuilt at same place with integration.

### **Relocation requirements for flood**

Strict formalities should be followed in making decision of relocation of the villages and towns. Giving priority to the original site should be considered in reconstruction plan, because the foundation of buildings can be reused and some of the infrastructures are still available. 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 with mainstream of the floodwater and with concentration of floating goods.
- Prohibiting to make construction at the site nearby the assigned flood-diversion sluices.

### **Detention basin development**

Floods in China's Yangze River used to inundate many thousands of square meters almost every year, claiming the lives of thousands of people. The detention basins are effectively used to direct the excessive flow over the design flood. 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 normally call detention 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.

During the 1954 great flood of 100-years frequency occurred in the Yangtze River, the maximum inflow above the Jingjiang section was 71,900 m<sup>3</sup>/sec, while the safe discharging capacity in this section was only 45,000 m<sup>3</sup>/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 detention basins on Yangze River is an unwise example of development of 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.

### **Reconstruction strategy following the 1991 Anhui Flood**

From May to July of 1991, an unprecedented flooding happened in Anhui. 278,000 houses collapsed, among which 165,000 collapsed to ground. 43 million people in the province were affected. The direct economic loss incurring from the disaster was nearly \$3.4 billion US. In the post-disaster reconstruction, The Provincial government carried out a strategy of government support and public participation, improvement of the people's living environment and disaster-proof capability building and multi-lateral cooperation. Most of the disaster-affected people had restored their normal livings by loan from the bank, donations from all parts of China and international agencies and from self-financing. The overall planning was made in the whole affected region and was carried out step by step according to the different situations

in different areas. By the end of 1995, 95% of the affected households have newly built their own brick-structure houses with better disaster-proof nature, and completely restored their normal life.

### **Land use following the 1976 Tangshan Earthquake**

The new Tangshan city was divided into three districts, namely the old district, the eastern coalmine district, and the Fengrun new district. They are separated by a distance of 25 km and consist of a triangle. Old district was rebuilt at the site of the former Lubei district. The eastern coalmine 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 were happened with relocation, such as people were not willing to relocate due to lack of good schools, hospitals and difficulties in getting job for their spouses.

### **Housing reconstruction**

Housing reconstruction plan was made immediately after the 1976 Tangshan earthquake. However, the potential households were not considered in the plan in Tangshan city. Lack of housing for the young couples were found after the completion of reconstruction, which took about 10 years.

After 1995 Hyogoken-Nanbu earthquake, the following measures were taken for reconstruction of housing.

- Hyogo Prefecture formulated Three-year Housing Reconstruction Plan in August 1995. An objective of the plan was to supply 125,000 housing units, including 38,600 units of disaster reconstruction public housing, 1,900 units of Redevelopment housing (excluding those for low-income earners), 16,800 units of reconstruction quasi-public housing, 44,500 units of privately-constructed housing and 23,200 units housing to be supplied by Housing and Urban Development Corporation and Hyogo Housing Supply Public Corporation. The target was achieved in 1999.
- As of 1 March 1999, 90% of the planned units (38,600 units) had been completed. Rent reduction for lower-income households and special care for the needs of the elderly have been taken into account in construction. The rent of disaster reconstruction public housing is set according to the income of the tenant and the location and size of the housing units at the level not be burden to the residents. For example, the monthly rent is 6,000 JPY yen for the first five years for a household with annual income of 1 million yen and 40m<sup>2</sup> of floor area (normally 30,000 yen). Silver Housing (3,896 units in 78 housing complexes) will be specially equipped with emergency assistance call and automatic safety confirmation system, which considers the lives of the elderly. Living Support Advisors will visit such housing to ensure the well being of the residents and to respond to emergencies. Collective housing (261 units in 8 housing complexes) which contains common space so that the elderly will be encouraged to actively benefit from the companionship and security offered in communal living and be kept from succumbing to loneliness.
- For low/middle-income households, a new measure, which lessens the initial burden of rent payments on renters for private-sector housing, was put into effect in October 1996. Those who lost their homes during the earthquake and are in the lower half of the income group are eligible for rent reduction and landlords, etc. are eligible for subsidies. For rent over 60,000 yen, the subsidy amount is 30,000 yen and 15,000 yen for FY 1996-1999 and 2000 respectively. For rent under 60,000 yen, 1/2 and 1/4 for FY 1996-1999 and 2000 respectively.
- Low-interest loan by the Housing Loan Corporation is offered to those who wish to rebuild their own houses. Coupled with interest subsidy measures under the Hyogoken-Nanbu earthquake Reconstruction Fund, the interest in such cases is substantially zero. In total, 77,000 households were benefit for the loan as of November 1998. A subsidy program for the elderly in demolishing and rebuilding their houses are being considered.

### **Life restoration after 1995 Hyogoken-Nanbu earthquake**

1. The Disaster-Victim Life Restoration Support law was enacted in May 1998
2. Because the new law shall not be applied retroactively to the Hanshin-Awaji case, the Disaster-Victim Independence Support Grant was established in Hyogo Prefecture. The Grant is 0.5-1.2 million yen to elderly, low-income, etc. households. The eligible households are those whose house was either fully collapse or severely damaged and dismantled, and who have resettled in permanent housing. About 120.4 billion yen have been provided to 124,000 households up to February 1999.
3. Various socio-economic measures were taken for restoration of life, such as:
  - Encouraging the discovery of worthwhile activities
  - Improving social welfare, medical and health care services
  - Supporting earthquake-affected children
  - Securing employment and providing financial support to promote independence
  - Information dissemination, consultation, setting up of supporters' network

### **Economy revitalization after 1995 Hyogoken-Nanbu earthquake**

1. Direct support measures to entrepreneurs. The Disaster Recovery Loan Program by government affiliated finance corporations and Disaster Recovery Financing System by Hyogo prefecture and Kobe City were established. Lower interest rate, Enlargement of loan upper-limit, extension of deferment and redemption are reflected in the program and system. Disaster Recovery Interest Subsidy by Hyogoken-Nanbu Earthquake Reconstruction Fund provides interest subsidy for 5 years and the interest rate becomes substantially zero.
2. Business infrastructure improvement projects, such as rental factory with reasonable rent, integration of local industry restoration with urban redevelopment, etc. are underway to facilitate restoration of the local industry.
3. Long-term strategic initiatives, including strengthening of the capacity of Kobe Port and initiating new industry structure generation projects (such as Kobe Luminarie and World Pearl Center etc.), are most concerned to ensure long-term economic development of the earthquake-affected area.

## **Improvement of Reconstruction Strategies**

### **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 for a contract of the extent of the damage.
- Both economic and social benefits should be considered in flood control projects evaluation since flood prevention works make 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 match national economy.
- Paying great attention to management and maintenance and establishing 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 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 “Integrated Disaster Reduction Plan” at national, provincial and county’s level and bring the plans into line with the economic and social development plan related;
- Buildings and structures shall meet 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.

### **Principles for Reconstruction Plan**

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

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

- Integrating strategies of disaster mitigation with that 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 service provision based on cost-benefit analysis, 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

### **Sediment deposition and decrease of flood diversion and flood storage capacity – lessons learned from 1998 great flood in China**

During the 1998 great flood in the Yangtze River, flood-peak stage was much higher than the maximum of that happened in the history although the peak flow was not reached to its maximum in the history. 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 river banks was greatly decreased. The total areas of the lakes connected with the middle reaches and downstream of the Yangtze river were 17,198 km<sup>2</sup> in 1950s. In 1980s, however, only 6,605 km<sup>2</sup> were left. That means it decreased by 61.5%. More than 30 billion m<sup>3</sup> of the volume of the lakes were lost.

### **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 immediately passed bitter experience and the concern in significant reduction in future risk foster improving safety in post-earthquake reconstruction. The survivors hope to build and to repair buildings and structures much better withstand shaking from future earthquakes.

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, are the key to solve the above mentioned pressures.

### ***System dynamics method***

It can be applied to analysis the complicated socio-economic system by computer simulation. In the phase of reconstruction, 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 requirement, determining the main variable, and collecting relevant data and analysing the relationship among different factors and variables;
2. Making causality feedback drawings and set up model frame, including determining modulars for the model or submodels and their modulars and making causality feedback return circuit diagram;
3. Making system flow chart by using system dynamics symbols;
4. Setting up DYNAMO equations, compiling 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, analysing 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 the quantitative analysis. The method consists of following steps:

#### 1. Problem Identification

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

#### 2. Structuring judgement matrix

#### 3. Arrange in importance order for hierarchy

For an element in one above hierarchy, the weight  $W_i$  of arrange in importance order for the element in present hierarchy and related to it can be calculated by the following formula:

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

Where, B is judgement 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 hierarchy general arrange in importance order less than or equals to 0.10 , it can be recognized as satisfactory consistency.

The hierarchy analysis model is established based on the following four principles:

- Enjoy priority in that closely related to people's life ;
- Enjoy priority in that closely related to national and regional economy development projects ;
- Enjoy priority in local key enterprises, and
- Postpone or cancel the construction of the 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 follows that after a damaging earthquake:

- Rehabilitation and reconstruction of the infrastructures, such as water supply, power supply, communication etc., shall be put in the first place ;
- More attention should be paid to the job generation and housing construction ; and
- **Attention should be paid to recover 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 1976 Tangshan earthquake based on the limit budget as shown in Figure 4. 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 property losses. The third cut was to identify critical buildings/structures in the identified critical institutions, for which damage or collapse will cause serious life loss and/or property losses. Then effective and economic strengthening procedures were followed.

## **Evaluation Models**

Post-earthquake activity model is an effective tool for evaluation of the result of the activities following a damaging earthquake. By 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

### **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 the segment, the affected 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 disaster are effectively reflected in future policies and the interests of regional or national progress, the following activities should be taken in the 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:

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

A typical post-earthquake reconstruction model is shown in Figure 5. Usually, for the first three phases, the duration of the latter phase is ten times more than that of the former.

**HAZARD, IMPORTANCE  
ECONOMICS**

**Geological hazard**  
- Basic intensity map  
- Medium-term prediction  
**Importance**  
- Political  
- Economic  
- Population

**List of  
critical  
cities/  
regions**

**1st cut**

**IMPORTANCE  
ECONOMICS**

**Political  
Economical  
Historical  
Occupancy  
Earthquake effect**  
- Secondary disaster  
potential  
- Social impact  
**Post earthquake rescue,  
recovery and  
reconstruction needs**  
- Emergency services  
- Life line system

**List of  
critical  
institutions/  
buildings**

**2nd cut**

**VULNERABILITY,  
ECONOMICS**

**Structure type  
Construction quality  
Design code followed  
Seismic capacity**  
(Analytical evaluation)  
**Constructive measures**  
(Constructive evaluation)

**List of critical  
Struct./Bldgs  
needed to be  
Strengthened**

**3rd cut**

**Strengthening  
Design**

Fig. 4 “Three cuts” process

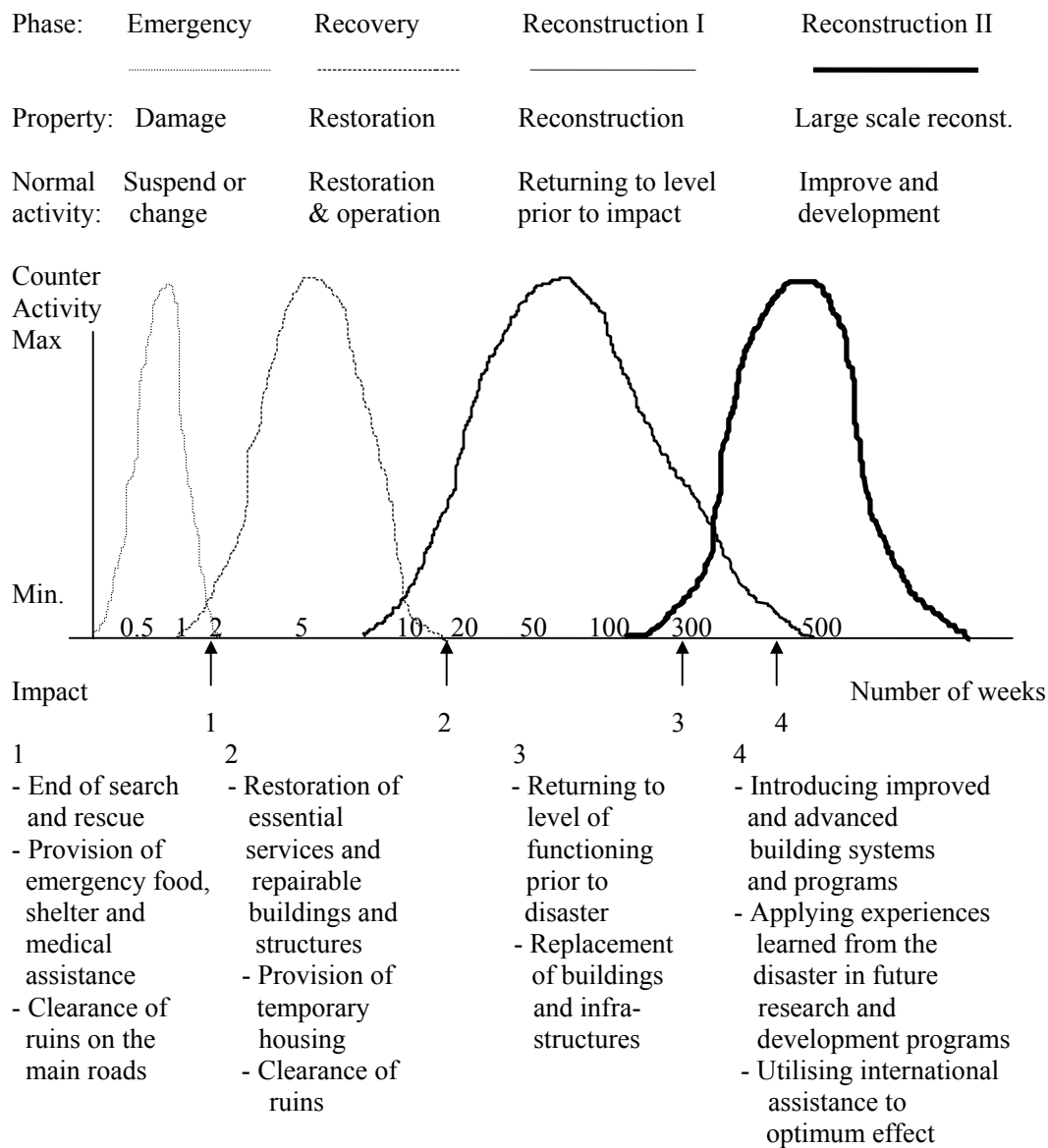


Fig.5 Typical Post-earthquake Reconstruction Activity Model

**Summary of relief and reconstruction experiences learned from the practices in the past decades**

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

1. Natural disaster is not only a natural phenomenon but also societal, economic, technological and environmental issues. For underdeveloped country or region post-disaster reconstruction is a good opportunity to change its original economy development model, to push the urban and rural renewal forward. Therefore, integrated reconstruction management is the key to accelerate reconstruction process and to improve human settlement environment.
2. Regardless of the precautions taken and the assurances given, a disaster can strike at any place at any time. Too many business executives and government officials, in many countries, remain in a state of

denial about this unshakable truth. It is far more responsible to plan and prepare for a disaster than to deny its possibility. Tangshan and Kobe were virtually destroyed by earthquake disasters that no one was prepared for because they were never supposed to happen!

3. Planning for reconstruction from a disaster must be realistic and reflective. This requires an accurate business impact analysis to determine what needs to be recovered and how long a period of time that reconstruction can consume without adversely impacting a business. In addition, a well-drilled recovery plan is required to ensure that the recovery process can be successfully implemented. Without a plan, it is impossible to predict or expect a successful recovery.
4. Bring the initiative of the local governments into full play is a key issue of integrated disaster management. Yet experience and modern disaster management practice recognize the importance of a strong and well-structured local disaster management capacity, and the need for decentralized authority to achieve an effective response. During a disaster, local governments are immediately confronted with the responsibility of providing relief to victims but often do not have the means nor adequate legislative authority to mobilize these resources. Local governments also have difficulties in accessing mitigation funds because funding and relief agencies typically work directly with central governments (Fig.5). Reaching out to local governments to help them build local capacity, acquire knowledge and resources and providing them with authority for decisions are essential policies for reducing losses. Although there is no standard practice or methodology for disaster management applicable to every city there is a common process of urban disaster risk reduction that must include analyzing disaster risk, building institutional knowledge, and integrating disaster management into day-to-day government action supported by dedicated financial and human resources.

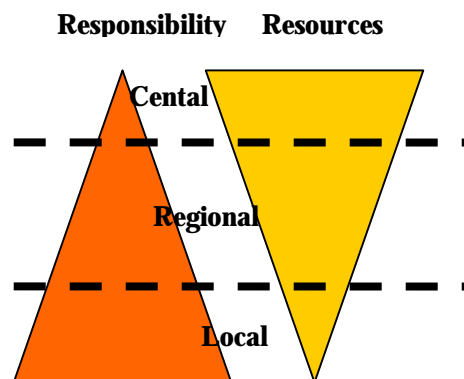


Fig.6 Unbalance of immediate disaster response responsibility  
Versus available resources of local government (From Fouad Rendimerad)

5. 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 neighbouring place 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
  - Economically feasible.
6. It is necessary to identify priority for recovery of economic sectors because financial resources are limited. The system dynamics method, analytical hierarchy process method, and “three cuts” process can be used for this purpose.

7. Post-earthquake reconstruction activity consists of four phases: Emergency, Recovery, Reconstruction I, and Reconstruction II. Post-earthquake reconstruction model based on these phases is an effective tool to evaluate the results of reconstruction activity and the effect of policies.
8. 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 plan; and Sound reconstruction planning.
9. The important role of re-use of debris and waste management following a natural disaster are usually neglected or underestimated. Although some of the debris, including bricks, wiring and plumbing, were recycled and re-used in the reconstruction process in China, it was in very small scale and mainly by hand. Although recycling bricks by hand is a slow and labor-intensive form of recycling, it can save debris transportation and tipping costs and valuable resources. At the same time, it can help immediate local job generation and solve clean-up problems.

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