

Earthquake Disasters in China

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Abstract Due to its geological conditions, China is one of the most seismic hazard-prone countries in the world. This chapter first introduces the spatial and temporal patterns of seismic activities and earthquake disasters in China. Seismic risk is then systematically assessed by combining peak ground acceleration (PGA) and building vulnerability curves, and an earthquake disaster risk map with regard to direct economic losses is obtained. Finally, the earthquake emergency response process, disaster response mechanisms, and post-disaster restoration and reconstruction processes are analyzed using the Wenchuan Earthquake case.

Keywords Earthquake disaster · Spatiotemporal pattern · Earthquake risk · Wenchuan Earthquake

Located at the junction of the circum-Pacific seismic belt and the Mediterranean-Himalayan seismic belt, China is one of the countries with most intense continental seismic activity, and earthquake disasters have been one of the most important natural disasters affecting China. According to the statistics, in the Chinese mainland, on average there are 19 earthquakes with magnitude above 5, 4 earthquakes with magnitude above 6, and 0.67 earthquakes with magnitude above 7 every year. Earthquake threats facing the Chinese cities are especially serious. Twenty-two provincial capital cities and 2/3 of the large cities that have more than one million population are located in high seismic hazard regions. Among these, 11 provincial capital cities have the possibility to encounter large earthquakes above magnitude 7 and 17 provincial capital cities have the possibility to encounter large earthquakes

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above magnitude 6.5 (Chen et al. 2005). Since the founding of the People Republic of China, the China Seismological Bureau and other related government departments have been established to carry out the development of seismic intensity zoning map and seismic observation network, development of zoning map for ground motion parameters, national earthquake safety plan, and other large projects, laying solid foundation for effectively reducing earthquake risks. The large-scale Observation Network for Crustal Movement in China project has fundamentally improved the backward situation of dynamic monitoring for the Earth's surface crust in China, improved the ability to forecast great earthquakes, and placed China at an advanced level of scientific and technological development internationally for monitoring and studying present-day crustal movement. Seismic disaster risk research has a very positive impact on reducing seismic losses and establishing earthquake-safe communities.

Since 1999, with the support of the Swiss Reinsurance Company, the Ministry of Civil Affairs (MOCA), Ministry of Science and Technology (MOST), and other relevant government departments, the authors have participated in the "Analogy Model for Seism Losses in China" project entrusted by the Swiss Reinsurance Company, the "Research and Demonstration for Key Technologies of Comprehensive Risk Prevention" national science and technology support project (2006BAD20B00), and the rapid assessments for disaster situations of the Wenchuan Earthquake in 2008 and Yushu Earthquake in 2010, as well as the "Technology for Comprehensive Disaster Risk Analysis" sub-project of an national science and technology support project (2008BAK49B04), and the "Technological Research for Risk Evaluation of Natural Disasters in the Yangtze River Delta Area" (2008BAK50B07). We have successively carried out a series of research on spatial and temporal pattern identification, fragility analysis, risk evaluation, and other aspects of seism disasters in China. Contents of this chapter are the integrated summary for the above studies.

1 Spatial and Temporal Patterns of Earthquakes

Situated at the junction of the circum-Pacific seismic belt and the Mediterranean-Himalayan seismic belt, China experiences most intense seismic activities and is one of the most earthquake-prone areas in the world (Wang et al. 2006). Seism in China is characterized by high frequency, wide distribution, great intensity, shallow seismic focus, and clear regional differences.

1.1 Spatial Distribution of Seismic Activities

China has rich historical earthquake data. The recorded most ancient earthquake can be traced back to the twenty-third century BC (DEDP 1995). According to the

historical earthquake data, destructive earthquakes have happened in 34 provinces, municipalities, and autonomous regions. Considering that early earthquake records may not have included some strong earthquakes, the earthquake data used in the analysis of this chapter are only from the twentieth century onward.

Most earthquakes in China are shallow focus earthquakes that occurred within the continental crust, with strike-slip type as the principal type; therefore, the horizontal distribution of epicenters can well represent the seismotectonic framework. Figure 1 shows the epicenter distribution of historical earthquakes in China (1900–2014).

From Fig. 1, we can clearly see that seismic activities of inland areas in China is much higher in the west as compared to the east. Seismic activities in western China is characterized by high frequency and great intensity.

According to Lou (1996), the boundary between eastern and western inland China seismic regions is the line connecting Baoji, Hankou, and Guiyang (around 107.5° E). Statistics for seismic activity frequencies in China (1900–2014) based on this division are shown in Table 1.

From the statistics we can see that between 1900 and 2014, the total number of seismic activities ($M_s \geq 6$) in China’s western inland is 8.28 times of that in eastern inland. In the recent over 100 years, there have been no earthquakes above magnitude 8, and only a few earthquakes above magnitude 7 in eastern inland.

To sum up, the spatial pattern of seismic activities in Chinese mainland is featured by strong activities in the west and weak activities in the east. The

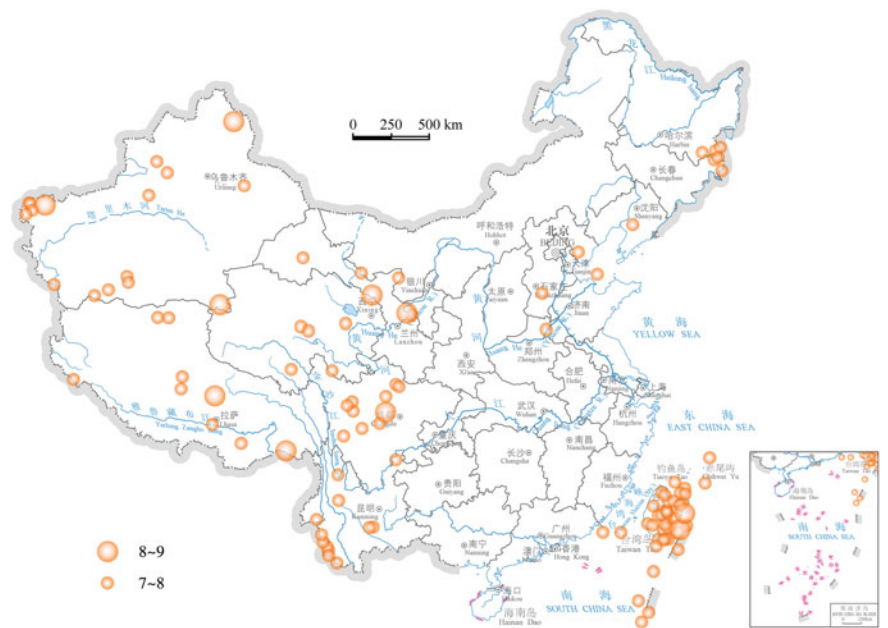


Fig. 1 Epicenters of historical earthquakes in China, 1900–2014

Table 1 Number of earthquakes in China's eastern and western inland, 1900–2014 ($M_s \geq 6$)

Region	$6 \leq M_s < 7$	$7 \leq M_s < 8$	$8 \leq M_s$	Sum
Eastern mainland	35	11	0	46
Western mainland	324	49	8	381
Western: eastern	9.26:1	4.45:1	8:0	8.28:1

Data source CENC (2015), DEDP (1995, 1999)

earthquake-prone areas in China are Xinjiang, Qinghai, Tibet, Sichuan, (west) Yunnan, Hebei, Taiwan, and other eastern provinces.

First, according to the geologic structure, the western inland area can be divided into Xinjiang seismotectonic zone and Qinghai–Tibet seismotectonic zone.

Xinjiang seismotectonic zone: Earthquakes in this area are related to the movements of the huge Cenozoic compressional basins and the orogenic belts in between. There have been very few earthquakes in the Junggar Basin and the Tarim Basin due to their rather stable interiors. The Tianshan Mountains and the Altai Mountains among it upheave intensely, so earthquakes mostly occur at the junction of these mountains and the plains. The earthquake faults are EW strike or NW strike; the faults in NW strike or NNW are mostly the compression and right-slip type.

Qinghai–Tibet seismotectonic zone: This area includes the entire Qinghai–Tibet Plateau and the western part of the Sichuan–Yunnan Plateau. As the region with the most active inland earthquakes in the world, earthquakes above magnitude 7 in the Qinghai–Tibet Plateau account for 43 % of the same magnitude earthquakes in the whole Eurasia, and more than 60 % of the same magnitude earthquakes in Chinese inland. The Qinghai–Tibet plate is located in the north of the subduction zone of the Indian plate and Eurasian plate, with an average elevation of 4,000 m. The Indian plate continuously subducts and compresses northward, which is the major driving force source. This area has the greatest crustal thickness in China, with average thickness of 50 km, and highest of about 73 km. Earthquakes in Qinghai most concentrate in the fracture system spreading in NW–EW–NNW strike and fracture with NE and SN strikes (Ma et al. 1982).

Table 2 shows seismic activities of six provinces (autonomous regions) that experience frequent earthquakes in China's western earthquake zone from 1900 to 2014. From the table, we can see that earthquakes with the highest intensity happened in Xinjiang and Tibet, but the region with the highest earthquake frequency per unit area is in Yunnan and Sichuan.

Second, to the east is the North China seismotectonic zone and the Taiwan seismotectonic zone.

North China seismotectonic zone: Many large earthquakes have occurred in this region since 1949, including the magnitude 6.8 Xingtai Earthquake in 1966 and the magnitude 7.8 Tangshan Earthquake in 1976. Since the Neogene, tectonic movements in this region have been very intense, deep structures manifested as the crust thinning and upper mantle upheaving, some low-velocity layer within local crust are also found; shallow structures manifested as the formation of rift valley and

Table 2 Seismic activities of six provinces (autonomous regions) in China's western earthquake zone, 1900–2014

Province (autonomous region)	Greatest earthquake			Earthquake of $M_s \geq 7.0$			Earthquake of $M_s \geq 5.0$		
	Magnitude	Rank		Frequency		Area frequency Times/ 10^5 km ²	Frequency		Area frequency Times/ 10^5 km ²
				Times	Rank		Times	Rank	
Yunnan	7.8	4		11	2	2.86	303	3	78.80
Xinjiang	8.25	2		17	1	0.98	483	1	29.54
Tibet	8.6	1		9	4	0.75	419	2	34.75
Qinghai	7.7	5		6	5	0.67	176	5	24.54
Gansu	8.0	3		4	6	0.99	59	6	14.50
Sichuan	8.0	3		10	3	2.08	192	4	39.82

Data source CENC (2015), DEDP (1995, 1999)

graben basin as well as fault activities. The strikes of tectonic lines are mainly NNE, followed by NW strike.

Taiwan seismotectonic zone: This zone includes Taiwan Province and its adjacent waters and is the region with the most frequent seismic activities in China. The occurrence of earthquakes related to the Pacific arc tectonic, Taiwan Island, and the surrounding active tectonic movements (including volcanic arc, intermountain depression, depression of the western edge of Cenozoic fold belt). The earthquake faults appear in NNE strike, with reverse-left-lateral strike-slip.

1.2 Temporal Distribution of Seismic Activities

Ma and Jiang studied the records of continental earthquakes in China in the past about 2,000 years and found that the alternation between periods of strong and weak earthquakes, and frequent and less frequent earthquakes is clear, and defined the periods with more frequent and high strength seismic activities as seismic active episodes, and periods with less frequent and low strength seismic activities as seismic inactive episodes (Ma and Jiang 1987). For example, in the twentieth century, $M_s \geq 7$ earthquakes in the Chinese mainland and its adjacent areas showed clear phases, with a duration of active episodes of 13–16 years and duration of largely stable inactive episodes usually of about eight years. The active episodes are: (1) 1897–1912; (2) 1920–1937; (3) 1946–1957; (4) 1966–1976; and (5) 1985 onward (Fig. 2). The time interval between active episodes is the inactive episodes, during which there were relatively fewer strong earthquakes and rarely any $M_s \geq 8$ earthquake.

We analyzed the earthquake data of $M_s \geq 7$ from 1987 to 2009 using the same method (Ma and Jiang 1987) and found that the ending year for the fifth earthquake active period was 2001 and the starting year of the sixth episode was 2008, with the 12 May 2008 Wenchuan Earthquake.

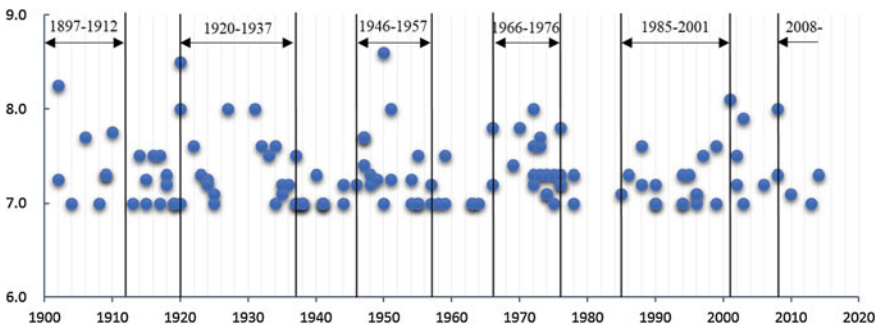


Fig. 2 Six seismically active episodes in Chinese mainland and its adjacent areas (Data source CENC 2015; DEDP 1995, 1999)

The spatial distribution of seismic activities for every earthquake active episode is different. In each episode seismic activities concentrated at one or two seismic belts, and these varied greatly among the episodes.

The main activity area of the first episode was the NE tectonic zone from Pamir to Baikal; the second episode was in the NW tectonic zone along the Hexi Corridor in Gansu; the main activity area of the third episode was the nearly NS seismic belt from eastern Tibet to central Mongolia; the fourth episode included the Sichuan–Yunnan seismic area and the North China seismic area. The main activity area of the fifth episode was the Kunlun Mountains seismic belt. On 14 November 2001, a Ms8.1 violent earthquake occurred in the Kunlun Mountains, which was the second greatest earthquake within Chinese mainland since the founding of the People's Republic of China in 1949, and ranked only second to the Ms8.5 earthquake in Tibet Medog on 15 August 1950.

According to the records of historical earthquakes and disasters in China (Lou 1996), between the sixteenth and seventeenth century and since the twentieth century, seismic activities were relatively intense while in the fifteenth century and the eighteenth to nineteenth century, seismic activities were relatively weak. As the frequency record of medium and strong earthquakes in the past over 100 years (Fig. 3) indicates, during this time period, earthquake frequency showed an increasing trend. Between 1949 and 2000, at least 50 medium or strong earthquakes struck each year, which is evidently higher than that between 1897 and 1949. Especially since 1999, the frequency of earthquakes clearly has been increasing. If the sixth phase of earthquake active period follows the same pattern as the previous phases, the Chinese mainland area is in the middle of a period of concentrated earthquake occurrences.

Since 1990, the annual fluctuation of death tolls from earthquakes in China has been great and serious disasters and heavy losses occurred frequently. Except 1996, 2003, 2008, 2010, and 2013 during which serious earthquakes happened, annual death tolls from earthquakes were less than one hundred, which indicates that with the socioeconomic development earthquake disaster prevention level has been improving and people's awareness to earthquake disaster has also increased. As a

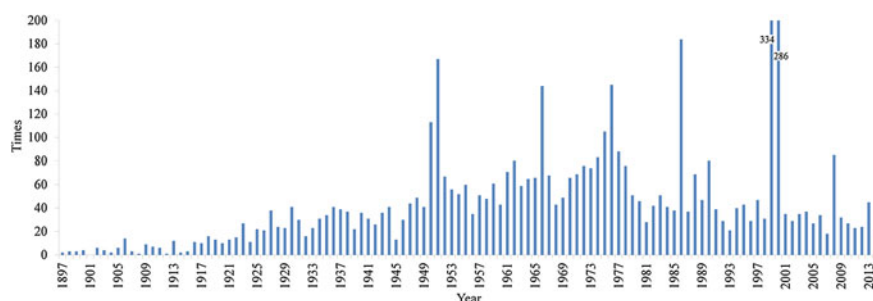


Fig. 3 Annual change of the number of medium and strong earthquakes in China, 1897–2014 (Data source CENC 2015; DEDP 1995, 1999)

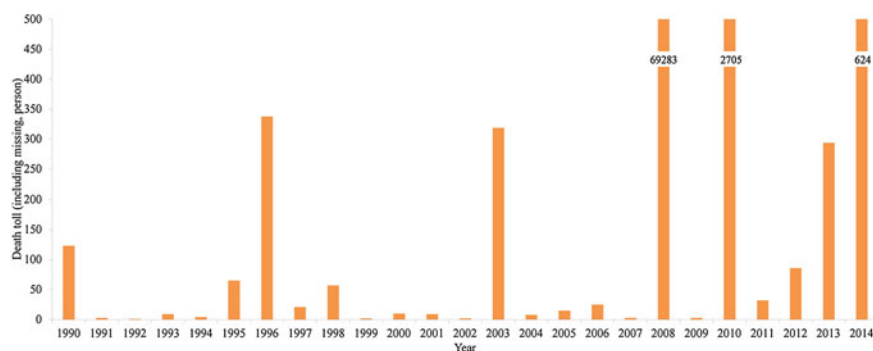


Fig. 4 Deaths and missing people from earthquakes in China, 1990–2013 (Data source Lou 1996; MCA 2015)

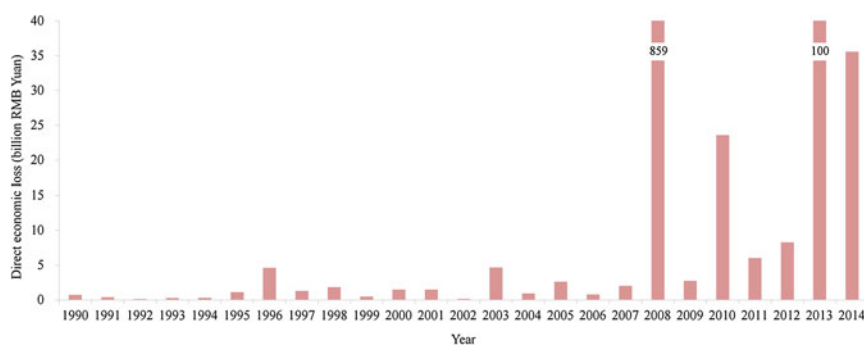


Fig. 5 Direct economic losses caused by earthquakes in China, 1999–2014 (Data source Lou 1996; MCA 2015)

result, the ability to protect life in earthquakes has clearly improved (Fig. 4). However, because of the continuous and rapid growth of the economy, in the recent 20 years, direct economic losses caused by earthquakes has evidently shown an increasing trend (Fig. 5).

2 Formation and Assessment of Earthquake Disasters

Based on existing research and literature, this section presents the fragility curves of different types of buildings in China and the spatial distribution of earthquake risks of provincial- and county-level administrative units based on a comprehensive consideration of earthquake hazard, exposure, as well as fragility, among other factors.

2.1 Earthquake Disasters and Their Assessment

China is one of the countries with the most serious earthquake disasters in the world. The Ms8.0 Wenchuan Earthquake and Ms7.1 Yushu Earthquake have successively occurred in China in recent years, with heavy casualties and huge economic losses.

Earthquake disaster analyses in China have resulted in various zoning maps of earthquake hazard. There are four versions of national earthquake zoning map of China.

In 1957, Lee and colleagues prepared the first generation earthquake zoning map of China, providing the intensity distribution of maximum earthquakes in the country (Lee 1957).

In 1977, the second version of earthquake zoning map of China was published, which was prepared using the medium-term and long-term earthquake forecasting method, providing maximum earthquake intensity that may be encountered within the future 100 years (Deng et al. 1980).

In 1990, the third version of earthquake zoning map of China was published, which was prepared using probability analysis method, providing the intensity value for the exceedance probability of 10 % in 50 years (Compiling Committee of Seismic Zoning Map in China 1992).

All the above three versions of the seismic zoning map adopt earthquake intensities as the mapping parameter.

The Seismic Ground Motion Parameters Zonation Map of China was published in 2001 (GB 18306–2001) (AQSIQ–SAC 2001), with the scale of 1:4,000,000. The single intensity parameter is hard to serve as a design response spectrum when seismic design enters the stage of considering response spectrum; therefore in China earthquake ground motion parameters (including the peak ground acceleration PGA and site characteristic period T_g) are also used in seismic zoning.

In the Seismic Peak Ground Acceleration Zoning Map of China (AQSIQ–SAC 2001), earthquake hazard is represented by the seismic peak ground acceleration value for exceedance probability of 10 % in 50 years, which is divided into seven subregions: region 7 ($PGA \geq 0.40$ g), region 6 ($PGA = 0.30$ g), region 5 ($PGA = 0.20$ g), region 4 ($PGA = 0.15$ g), region 3 ($PGA = 0.10$ g), region 2 ($PGA = 0.05$ g), and region 1 ($PGA < 0.05$ g).

According to the statistical analysis for the occurrence probability of earthquakes in the north, northwest, and southwest areas of China, the seismic intensity for exceedance probability of 63 % in 50 years is the normal intensity—the Code for Seismic Design of Buildings takes this as the first level of intensity; the intensity for exceedance probability of 10 % in 50 years is the basic seismic intensity (also the design basic seismic peak acceleration specified by the Seismic Ground Motion Parameters Zoning Map of China)—the Code takes this as the second level of intensity; the intensity for exceedance probability of 2–3 % in 50 years is the rare intensity—the Code takes this as the third level of intensity. Exceedance probability in 50 years, return period, and peak acceleration of different levels of seismic ground motions are shown in Table 3.

Table 3 Return period (year), peak acceleration (g, acceleration of gravity), and probability of three-level seismic ground motions

Level of seismic ground motion	Exceedance probability in 50 years (%)	Return period (year)	Peak acceleration					
			6°	7°	8°	9°		
Second level of intensity (seismic fortification intensity)	10	475						
First level (frequently occurred seism peak acceleration)	63	51	0.018	0.036	0.054	0.086	0.108	0.144
Second level (design basic peak acceleration)	10	475	0.050	0.100	0.150	0.200	0.300	0.400
Third level (rare seism peak acceleration)	2–3	1,642–2,475	0.120	0.225	0.324	0.405	0.540	0.630

Source Fang et al. (2011, p. 193)

The Seismic Ground Motion Characteristic Period Zoning Map of China (AQSIQ–SAC 2001) shows the three regions of seismic ground motion characteristic period under general site conditions (class II site): region 1 (0.35 s), region 2 (0.40 s), and region 3 (0.45 s).

In generating the Seismic Ground Motion Parameters Zoning Map of China, three assumptions were made: (1) seismic peak ground acceleration is not affected by local site conditions; (2) the influence of site conditions on design ground motion is mainly reflected in the characteristic period; and (3) the zoning of seismic ground motion characteristic period only specifies characteristic periods under general site conditions (class II site). In practice, however, we still need to adjust the characteristic periods according to site classifications based on geological survey data (Table 4).

At present, seismic hazard assessment is mainly based on the levels of historical seismic activity and tectonic conditions of activity, among others. The results of seismic hazard assessment may differ significantly from the actual occurrence of future large earthquakes. The Tangshan Earthquake, Wenchuan Earthquake, and Yushu Earthquake all occurred in areas of low-level seismic activity according to the knowledge prior to the events, and this indicates that the evaluation models, analysis methods, and results of seismic hazard at present are still far from adequate.

Table 4 Values of characteristic period

Subregions of characteristic period	Site classifications				
	I ₀	I ₁	II	III	IV
Region 1 (0.35 s)	0.20	0.25	0.35	0.45	0.65
Region 2 (0.40 s)	0.25	0.30	0.40	0.55	0.75
Region 3 (0.45 s)	0.30	0.35	0.45	0.65	0.90

Source AQSIQ–SAC (2001)

In order to meet the requirements of social and economic development for earthquake prevention and disaster reduction, it is necessary to pay closer attention to research on seismic fragility of potential hazard-affected units and seismic hazard levels, and take reducing seismic disaster risk and developing long-term management approaches of seismic disaster risks as an important part of disaster prevention and mitigation.

2.2 Fragility of Buildings and Assessment

Destruction status and loss ratio of buildings: According to the *Post-Earthquake Field Works—Part 4: Assessment of Direct Loss* (GB/T 18208.4–2005) (AQSIQ–SAC 2005), the extent of damage of buildings can be divided into five types: basically intact, slightly damaged, moderately damaged, severely damaged, and completely destroyed. The loss ratios of buildings of different damage status are shown in Table 5.

Classification and fragility of buildings: Buildings can be classified according to the type of structure, time of construction, number of storeys, height, level of earthquake fortification, geographical location, and so on.

Construction time of buildings in China can be divided into five periods: before 1978, 1978–1989, 1990–2000, 2000–2010, and after 2011.

Geographical location mainly determines the outer wall thickness of masonry buildings under different climatic conditions. In Heilongjiang, Xinjiang, and other northern China provinces, for example, the outer wall thickness of masonry structures is usually 49 cm. In the North China area, this is usually 37 cm; and in southern China provinces, it is usually 24 cm. For brick masonry buildings, the influence of climate on outer wall thickness shall be taken into consideration.

Based on the consideration for seismic performance combined with the classification of buildings in the China Statistical Yearbooks, the type of buildings can be divided into: Type A (mainly reinforced concrete structure); Type B (mainly brick-concrete structure); Type C (mainly brick-timber structure); and Type D (mainly raw-soil structure and dry-laid stone houses). For Type A and Type B buildings, their seismic performance in various seismic fortification subregions

Table 5 Loss ratio of buildings of different damage status

Type of building	Destruction level				
	Basically intact	Slightly damaged	Moderately damaged	Severely damaged	Completely destroyed
Reinforced concrete, masonry buildings	0–5	6–15	16–45	46–80	81–100
Industrial factory buildings	0–4	5–16	17–45	46–80	81–100
One-storey houses in cities and towns, farm buildings	0–5	6–15	16–40	41–70	71–100

Source AQSIQ–SAC (2005)

(seven in total) with different design basic seismic ground motion is different, so Type A and Type B buildings can be classified into seven subclasses, as shown in Table 6. The purpose of this simple classification is to extract statistical data on the spatial distribution of buildings in the China Statistical Yearbooks. More detailed data on the spatial distribution of building types are largely unavailable at the national level.

For different types of buildings, the peak acceleration of seismic ground motion S_a is used as a random variable to describe the fragility characteristics. Assuming that the fragility curve of buildings is the normal distribution function for logarithm ($\ln(S_a)$) of S_a (peak acceleration of seismic ground motion), each destruction status d_s has a corresponding fragility curve.

Assuming that the mean value of S_a under a certain destruction status is $E(S_a)$, the variance is $\text{Var}(S_a)$, then the mean value (μ) and variance (σ^2) for the logarithm of S_a are respectively

$$\mu = \ln(E(S_a)) - \frac{1}{2} \left(1 + \frac{\text{Var}(S_a)}{[E(S_a)]^2} \right). \tag{1}$$

Table 6 Classification of building types

Seismic performance categories of buildings	Main types of building structures	Subregions of design for earthquake	Design basic seismic acceleration	Classification of building types
Type A	Reinforced concrete structure and steel structure	Region 1	None	Region 1 of Type A
		Region 2	0.05 g	Region 2 of Type A
		Region 3	0.10 g	Region 3 of Type A
		Region 4	0.15 g	Region 4 of Type A
		Region 5	0.20 g	Region 5 of Type A
		Region 6	0.30 g	Region 6 of Type A
		Region 7	0.40 g	Region 7 of Type A
Type B	Brick-concrete structure	Region 1	None	Region 1 of Type B
		Region 2	0.05 g	Region 2 of Type B
		Region 3	0.10 g	Region 3 of Type B
		Region 4	0.15 g	Region 4 of Type B
		Region 5	0.20 g	Region 5 of Type B
		Region 6	0.30 g	Region 6 of Type B
		Region 7	0.40 g	Region 7 of Type B
Type C	Brick-timber structure	–	–	Type C
	Masonry structure			
Type D	Raw-soil structure and dry-laid stone houses	–	–	Type D

Source Fang et al. (2011, p. 194)

$$\sigma^2 = \ln \left(1 + \frac{\text{Var}(S_a)}{[E(S_a)]^2} \right) \quad (2)$$

The expression of fragility curve under a certain destruction status d_s is

$$P[d_s|S_a] = \Phi \left[\frac{\ln(S_a) - \mu}{\sigma} \right] \quad (3)$$

where, Φ is the curve for cumulative probability of standard normal distribution.

The points on the fragility curve under a certain destruction status refer to the probability of buildings reaching or exceedance a certain destruction status under the action of a certain S_a . The fragility curve under a certain destruction status is determined by the mean value of spectrum displacement $E(S_a)$ and variance $\text{Var}(S_a)$. The variance of fragility curve shows the variation range—the greater the variance, the gentler the fragility curve; and the smaller the variance, the steeper the fragility curve.

According to the survey for historical earthquakes in china and the results of existing research (Yin et al. 2003; Yin and Yang 2004), this chapter provides the fragility curves for different types of buildings, as shown in Fig. 6.

Unit construction cost for different building types: The unit construction cost of buildings can be determined according to the building types listed in Table 7.

2.3 Earthquake Disaster and Post-disaster Rapid Loss Assessment

Earthquake disaster is the result of seismic hazard, vulnerability of earthquake disaster-affected bodies, and their exposure. Due to the limited availability of data and limitations of modeling, in post-disaster rapid loss assessment we only consider the damage state and number of damaged buildings, direct economic losses from building damages, and the number of affected people. Using the earthquake magnitude and epicenter parameters, the assessment is composed of three steps: (1) determine the spatial distribution of population and buildings by collecting population and socioeconomic data and combining them with land use data; (2) evaluate the degree of exposure of disaster-affected bodies, including population and buildings; (3) determine earthquake-related losses based on the assessment results of the exposure of disaster-affected bodies and building vulnerability.

Based on the experiences in post-earthquake loss assessment of the Wenchuan Earthquake (Xu et al. 2008) and the Yushu Earthquake (Xu et al. 2011), Fig. 7 presents an improved framework of earthquake loss assessment using empirical models:

First, retrieve data for the earthquake parameters (earthquake magnitude and epicenter location) published by the China Earthquake Administration. Select either

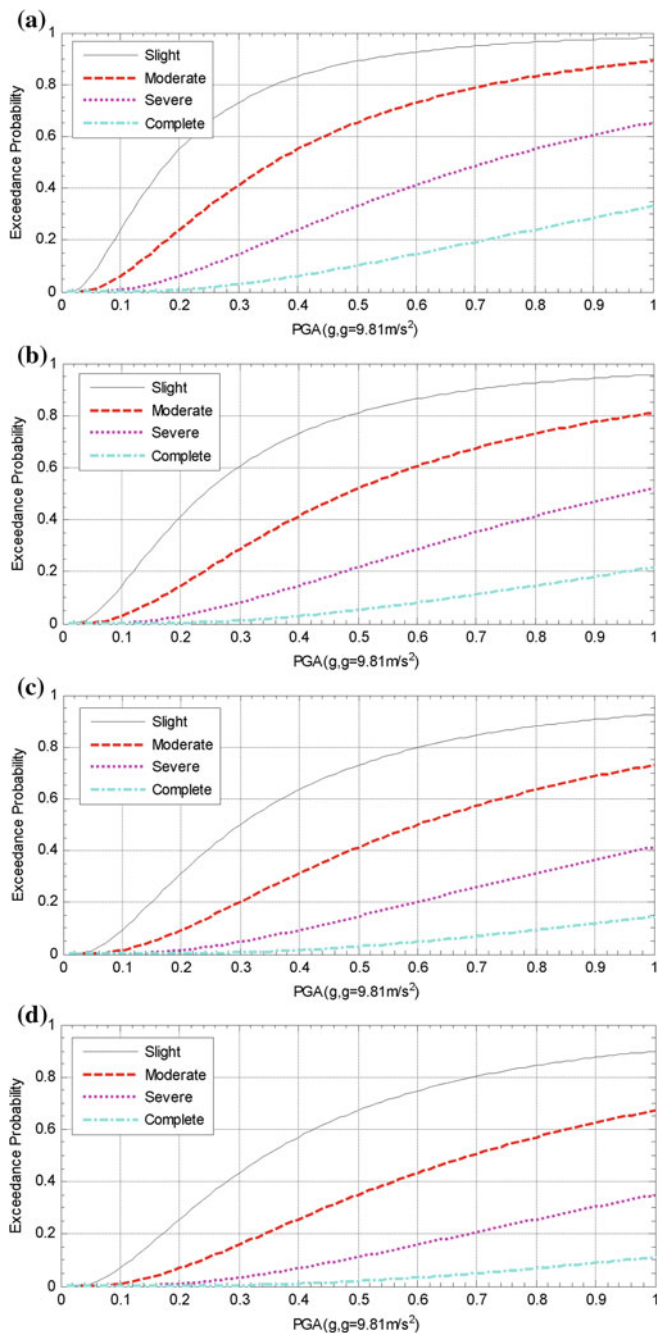


Fig. 6 Fragility curves for buildings by different damage status. **a** Type A in Region 1. **b** Type A in Region 2. **c** Type A in Region 3. **d** Type A in Region 4. **e** Type A in Region 5. **f** Type A in Region 6. **g** Type A in Region 7. **h** Type B in Region 1. **i** Type B in Region 2. **j** Type B in Region 3. **k** Type B in Region 4. **l** Type B in Region 5. **m** Type B in Region 6. **n** Type B in Region 7. **o** Type C. **p** Type D (Source Fang et al. 2011, p. 194–198)

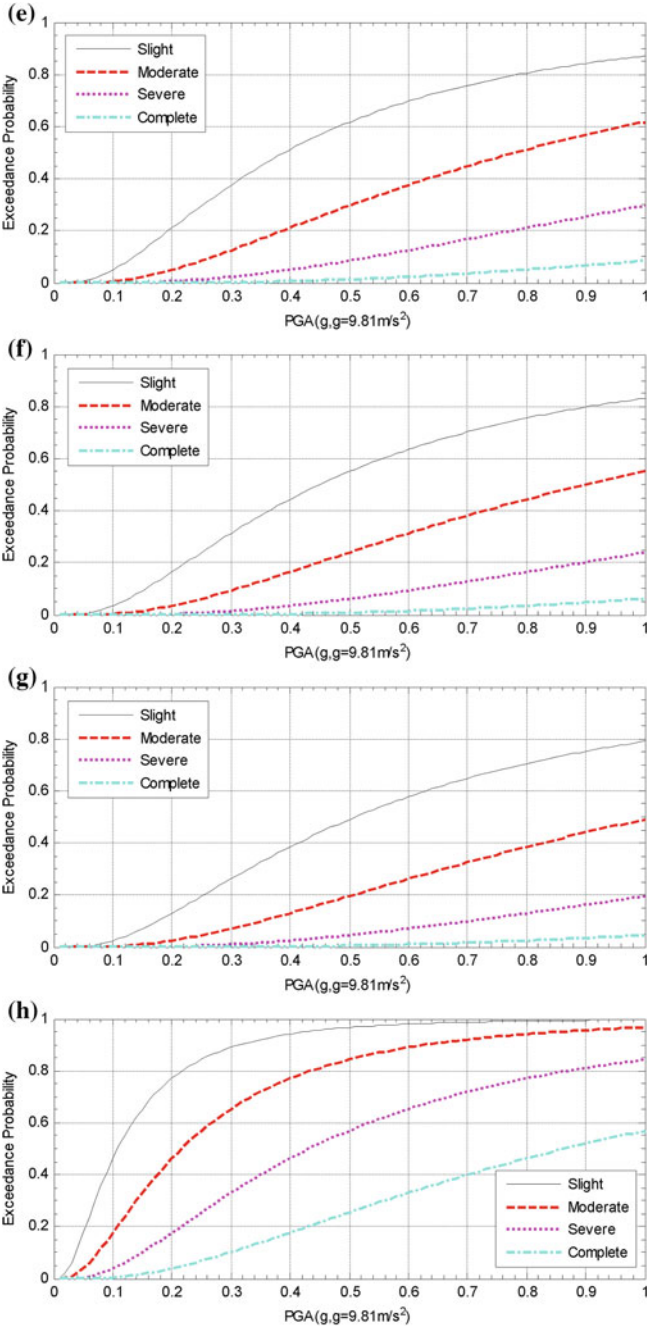


Fig. 6 (continued)

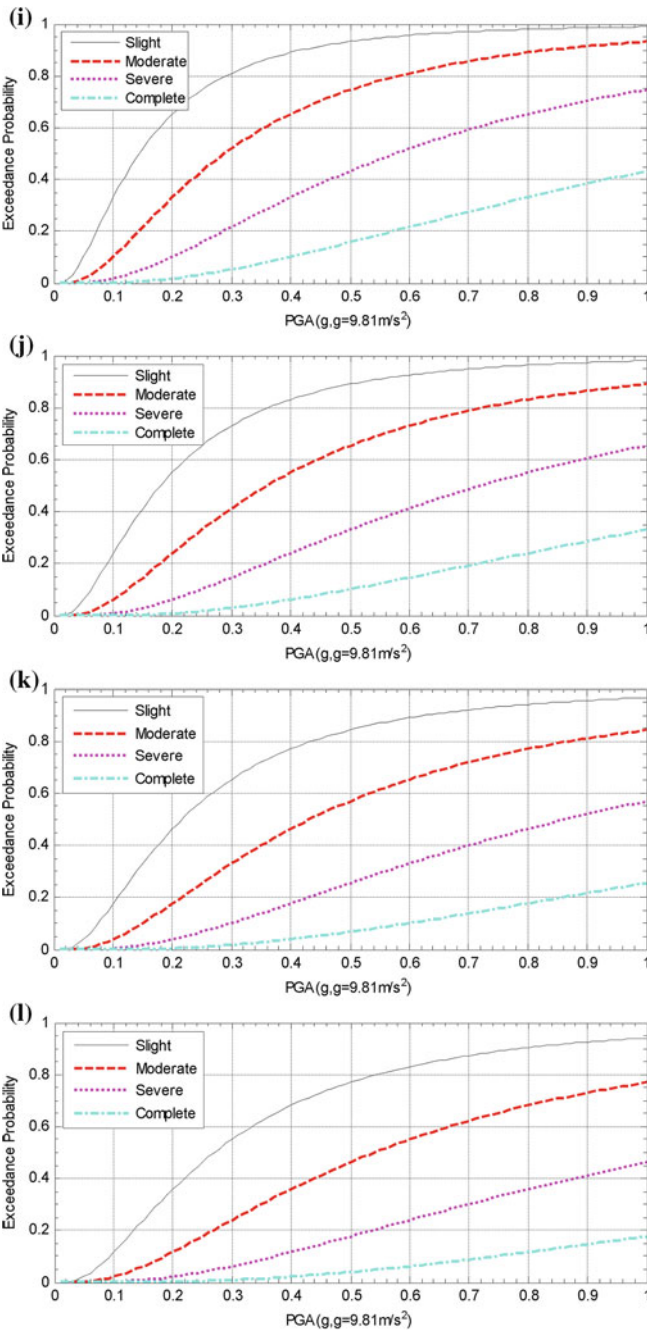


Fig. 6 (continued)

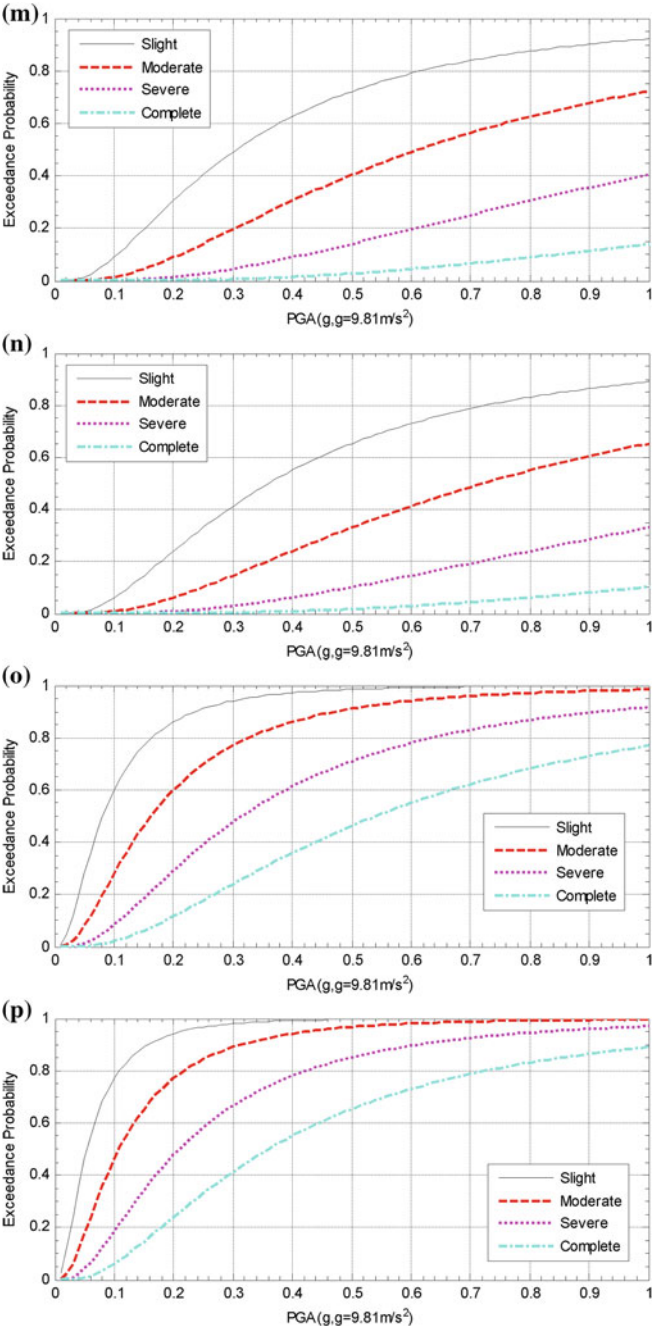


Fig. 6 (continued)

Table 7 Unit construction costs for different building types

Types of houses	Type A	Type B	Type C	Type D
Unit cost (RMB Yuan/m ²)	2,200	1,600	1,000	600

Source Fang et al. (2011)

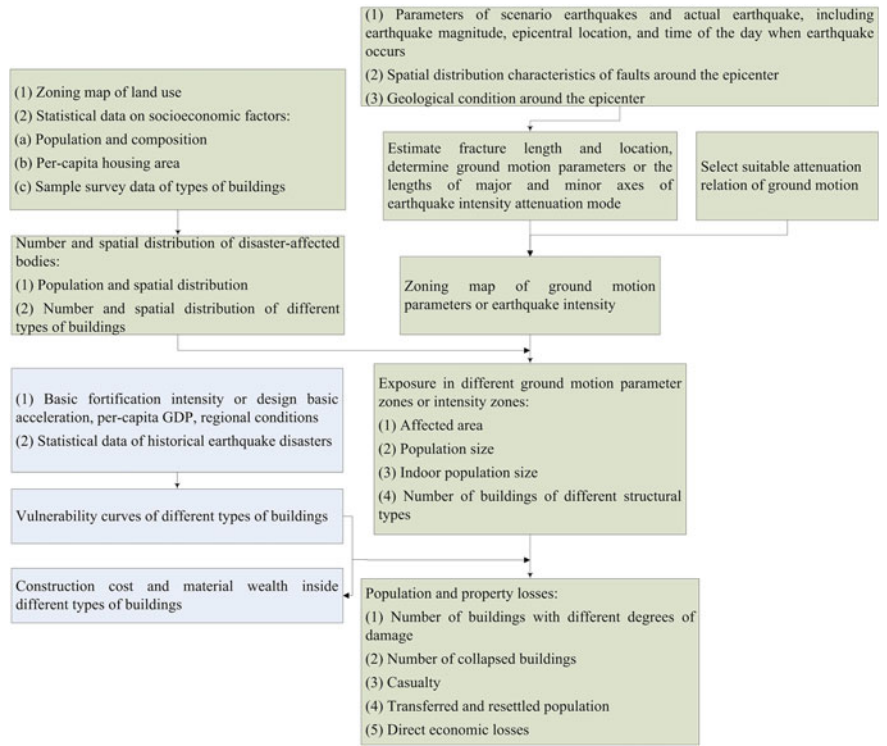


Fig. 7 Earthquake disaster and the framework of post-disaster rapid loss assessment based on empirical models

a point source model or a line source model according to earthquake magnitude, fault spatial distribution characteristics, and seismic geological condition around the epicenter.

In the current practice, spatial distribution models of isoseismic line are the following types: (1) elliptical model based on point source; and (2) equal fault throw model based on fault fracture line. The choice of isoseismic line model shall be made in accordance with the earthquake magnitude, depth of hypocenter, thickness of cover layer in epicentral area, and active structure. In the case of large magnitude earthquake (greater than 6.5), shallow depth of hypocenter, small cover thickness, and obvious active structure in epicentral area, equal fault throw model

based on fault fracture line should be used to compile isoseismic line plan; otherwise elliptical attenuation model based on point source should be adopted.

Second, select suitable attenuation relation model of seismic intensity, compile experiential peak acceleration or intensity isoseismic line chart in accordance with the model of earthquake source.

Third, according to the experiential ground motion parameter or intensity zonation plan and regional land use zonation plan and socioeconomic data (such as population size and composition, per-capita housing area, and sampling statistical data of structure type of buildings), determine the exposure data of different ground motion parameter zones or intensity zones, such as disaster area, population size, indoor population size and percentage, and the number of buildings with different structure types.

Fourth, based on historical seismic damage statistical data of the disaster area or seismic damage statistical data of similar areas and regional socioeconomic development level, earthquake fortification standard of buildings, construction date, and other regional characteristics, vulnerability curves of different types of buildings in the disaster area are calculated.

Fifth, calculate the damage degree of the population and property in different ground motion parameter zones or intensity zones according to the indoor population of different types of housing in the area, unit construction cost of buildings, material wealth inside the buildings, vulnerability of disaster-affected bodies using corresponding damage assessment models. Evaluate earthquake losses (such as the number of buildings with different damage degrees, the number of houses collapsed after the earthquake, the number of initial casualties, transferred and resettled population, and direct economic losses).

This loss assessment framework has been applied post-disaster in the rapid assessment of many earthquake disasters and has been constantly improved.

2.4 Earthquake Disaster Risk Assessment and Mapping

As a product of earthquake hazard, vulnerability of disaster-affected bodies, and their spatial distribution (exposure), earthquake disaster risk is the earthquake damage that an area may be subjected to in a certain period of time in the future. Earthquake disaster risk assessment evaluates the potential earthquake damage of disaster-affected bodies by taking into account potential earthquake hazard, vulnerability of disaster-affected bodies, and the potential degree of exposure of these units in the area.

Earthquake hazard analysis examines the probability of occurrence of earthquakes above a given intensity in a region within a certain period of time in the future. Vulnerability of disaster-affected bodies refers to the probability or possibility of certain degree of damage under the impact of certain earthquake intensity. Degree of exposure refers to the number of disaster-affected bodies or percentage that may be affected by the threat under certain earthquake intensity.

Here, disaster-affected body is a relatively broad concept, including industrial and civil constructions, infrastructure (such as roads and bridges, municipal pipelines, communication networks, embankment dams), population, and so on. Different types of disaster-affected bodies require different methods for vulnerability analysis.

Based on the definition of earthquake disaster risk, its result of analysis is composed of the following types:

Absolute risk: earthquake damage that may be suffered in an area within a certain period of time, including economic losses and casualties. The assessment result shows the total of potential earthquake losses for an area.

Relative risk: earthquake damage that may be suffered per unit area (or per capita or unit of assets) in an area within a certain period of time, including economic losses and casualties. The assessment result shows the relative earthquake risk per unit area of an area.

Single exposure unit risk: earthquake damage that a single disaster-affected body (building or people) may encounter in an area within a certain period of time. The assessment result can provide data support for the determination of premium rate of disaster-affected bodies in an area.

Figure 8 outlines the steps of earthquake disaster risk assessment:

First, determine the number and spatial distribution of each type of disaster-affected bodies. Size of the population and the number of different types of buildings can be determined using county-level administrative divisions, land use divisions, population and composition, proportion of different types of buildings, per-capita housing area, and so on.

Second, determine the ground motion parameter (peak acceleration or seismic intensity) under different return periods. Seismic Peak Ground Acceleration Zoning

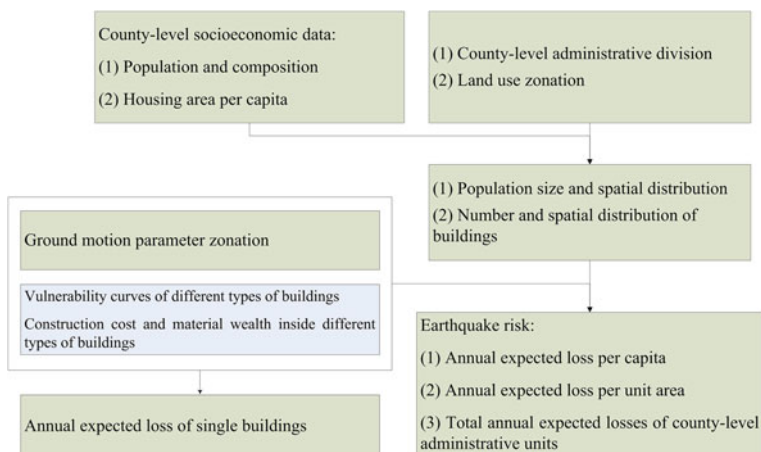


Fig. 8 Framework of earthquake disaster risk assessment (Source Fang et al. 2011, p. 199)

Map of China (AQSIQ–SAC 2001) indicates seismic peak ground acceleration with exceedance probability of 10 % in 50 years (the return period of these medium earthquakes is 475 years); the peak acceleration of strong and rare earthquakes (exceedance probability 2–3 % in 50 years, return period 1,642–2,475 years) and small earthquakes (exceedance probability 63 % in 50 years, return period 51 years) can be determined according to Table 3. Describe earthquake hazard using the three levels seismic peak ground acceleration.

Third, determine the building type and its vulnerability curve (see vulnerability assessment in this section for details).

Fourth, using building vulnerability curves and the three levels of ground motion peak acceleration to determine the annual mean expected earthquake loss rate of certain type of building; then determine the value of the earthquake disaster risk in the area according to the construction cost of different types of buildings and the number and spatial distribution of the disaster-affected bodies.

If annual expected earthquake disaster risk is measured by annual economic losses from building damages caused by earthquakes that may occur within the county administrative units, then the calculation formula is as follows:

$$R = \sum_p \left(C_p \times \sum_{j=I-1}^{I+1} \frac{L_{pj}}{Y_j} \right) \quad (4)$$

where, R is the annual economic losses from building damages that may occur within a county (RMB Yuan/year); p is the type of buildings. Seismic performance of buildings is divided into Type A (mainly of reinforced concrete structures), Type B (mainly brick-concrete structures), Type C (mainly masonry structures), and Type D (mainly raw-soil structures); C_p is the total construction cost of p type building; I is design basic earthquake intensity, $I - 1$, I , $I + 1$ are the corresponding intensity grade of a small earthquake, medium earthquake, and strong earthquake, respectively; Y_j is the return period of intensity grade j , which can be calculated according to the exceedance probability of strong earthquake ($I + 1$), medium earthquake (I), and small earthquake ($I - 1$); L_{pj} refers to the loss rate of p type building under intensity level j , and its calculation formula is:

$$L_{pj} = \sum_{ds=1}^5 DM_j(d_s) \times LR(d_s) \quad (j = I - 1, I, I + 1) \quad (5)$$

where, d_s is damage state ($d_s = 1, 2, 3, 4, 5$ refer to intact, slightly damaged, moderately damaged, severely damaged, and completely destroyed, respectively); $LR(d_s)$ is loss ratio when the damage state is d_s ; DM is earthquake damage matrix, $DM_j(d_s)$ is the percentage of d_s under j -level intensity.

Table 8 Mean loss ratio of buildings with different degrees of damage

Damage degree of building	Basically intact	Slightly damaged	Moderately damaged	Severely damaged	Completely destroyed
Mean of loss ratio	0.00	0.15	0.40	0.70	1.00

Data source Fang et al. (2011, p. 199)

The unit construction cost of buildings can be decided based on the building types in Table 7. Table 8 shows the mean loss ratio of buildings with different degrees of damage.

2.5 Earthquake Disaster Risk Mapping

Earthquake disaster risk database: risk database for earthquake damage in China is made up of three parts of data: (1) data for earthquake disaster-inducing factor; (2) data for disaster-affected bodies; (3) data for earthquake disaster risk level.

Database for disaster-inducing factor: data for earthquake disaster-inducing factor in China is composed of data for spatial distribution of seismic peak ground acceleration, historical earthquakes, and spatial distribution of active structures. These data are mainly published by the China Earthquake Administration.

Database for disaster-affected bodies in China: this database mainly includes data on land use, population and density, and the number and distribution of different building types. Using the data from the 1 % National Population Sampling Survey of 2005 and considering other local conditions, Type A, B, C, D buildings of each provincial administrative unit are estimated. According to the 2000 National Population Census data, determine the population (including urban population and rural population) and corresponding per-capita construction area of the county units. Based on land use types, assign the population and buildings to the corresponding plots.

Earthquake disaster risk database: this database includes land parcel-level earthquake disaster risk database and county-level earthquake disaster risk database. Where, land parcel-level earthquake disaster risk database is an integrated database including land use, earthquake hazard, and disaster-affected bodies data, loss data of the plot under the impact of design basic earthquake peak acceleration, and earthquake disaster risk data.

Compilation of the county-level administrative unit earthquake disaster risk map of China: Using land use and county-level socioeconomic data, earthquake hazard analysis results, and building vulnerability curves, prepare the land parcel-level earthquake disaster risk map for each province in China (1:10,000). Aggregate the land parcel-level earthquake disaster risk data into county-level data, then compile the county-level administrative unit earthquake disaster risk map of in China (Figs. 9, 10, and 11).

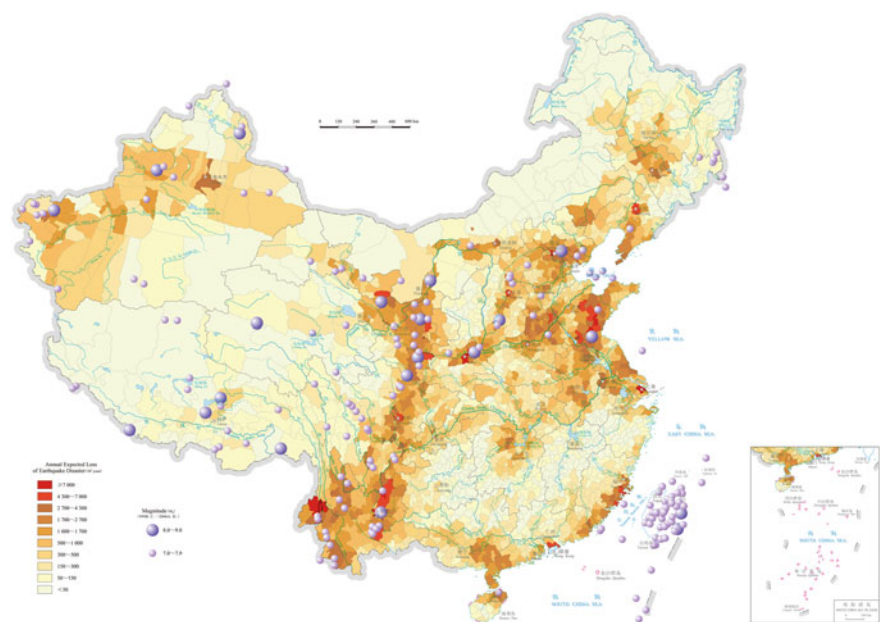


Fig. 9 County-level earthquake disaster risk map of China—Total annual expected losses (*Source* Shi 2011, p. 28–29)



Fig. 10 County-level earthquake disaster risk map of China—Annual expected losses per unit area (*Source* Shi 2011, p. 30–31)

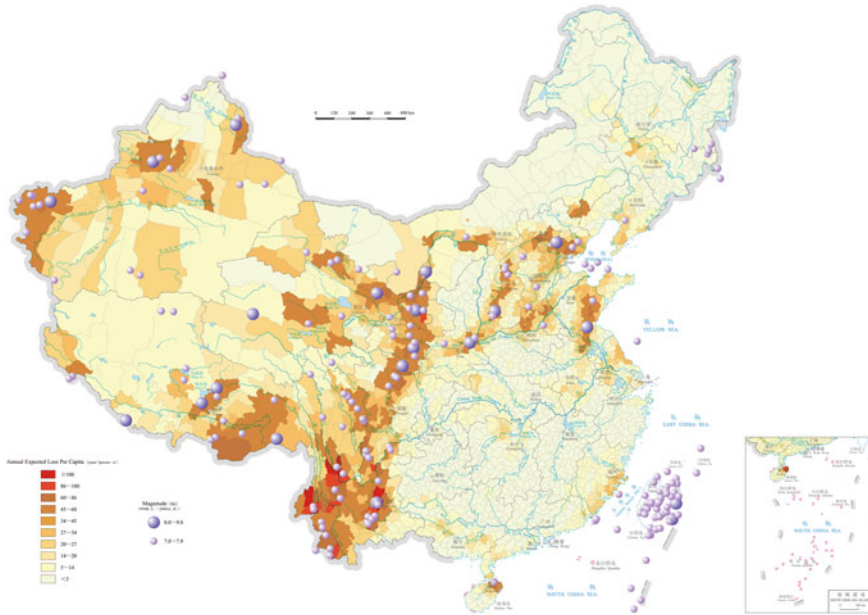


Fig. 11 County-level earthquake disaster risk map of China—annual expected losses per capita (Source Shi 2011, p. 32–33)

3 Assessment Result of Earthquake Disaster Risk of China

Total annual expected economic losses: this is calculated in order to indicate the total annual earthquake disaster risk of an area in the future. In addition to the earthquake hazard level of the area, total annual expected economic losses are also closely related to the size of the population, the total number of buildings, and earthquake resistance capacity of the area. In this chapter, county-level administrative units are taken as the spatial unit of analysis of the total annual expected losses. Figure 9 shows that the counties with higher total annual expected economic losses are mainly distributed on the east coast and in Gansu, Sichuan, and Yunnan Provinces.

Annual expected economic loss per unit area: under the condition that earthquake hazard is at the same level and the total earthquake resistance capacity of buildings is similar for different regions, if the population and the number of buildings in one area is higher, the total earthquake disaster risk of the area will be higher too. In order to better compare the relative degree of earthquake disaster risks in different areas, we normalize the annual expected economic losses into per unit area by administrative district. The annual expected economic loss per unit area

is closely related to the density of disaster-affected bodies in each unit of the land area. Figure 10 shows that the counties with higher annual expected economic loss per unit land area are mainly located on the North China plain, a number of east coastal provinces, and Gansu, Sichuan, and Yunnan Provinces.

Annual expected economic loss per capita: The per-capita annual expected economic loss indicator shows the average annual economic loss per capita caused by earthquakes in an administrative district in the future. This is to facilitate the comparison with the economic losses and disaster risks caused by other disasters. Per-capita annual expected economic loss is closely related to the earthquake hazard level at the place. The county-level administrative units with higher per-capita annual expected economic loss are mainly distributed in Yunnan, Sichuan, Shandong, and Ningxia (Fig. 11). Improving the seismic fortification level is an effective way to reduce the per-capita annual expected economic loss.

4 Responses to the 2008 Wenchuan Earthquake

4.1 Disaster Situation

At 14:28 on 12 May 2008, an Ms8.0 earthquake occurred in Wenchuan County, Sichuan Province. The epicenter was located at Yingxiu Town, Wenchuan County (31.0° N, 103.4° E), with focus depth of 14 km and epicentral intensity of XI degree. The aftershocks occurred more than 30 thousand times, involving 10 provinces and municipality including Sichuan, Gansu, Shaanxi, Chongqing, 417 counties (cities or districts), 4,667 towns, and 48,810 villages. The total disaster area was about 0.5 million square kilometers, wherein severely and very severely hit areas were 0.13 million square kilometers (Table 9), resulting in 69,227 deaths, 17,923 people missing, and 15.1 million people to be urgently transferred and resettled (Earthquake Relief Experts Group of National Committee for Disaster Reduction and Ministry of Science and Technology 2008). A large number of houses collapsed or were damaged, large area of infrastructures was damaged, agriculture and industrial production encountered great losses, ecological environment was severely damaged, and direct economic losses were over RMB 845.1 billion Yuan. Severe secondary disasters such as rock collapse, landslide, mud-rock flow, and formation of barrier lake were also prevalent. The affected area in Sichuan Province alone was 0.27 million km². Disaster areas of Sichuan mainly involved 20 prefectures and cities, including A'ba, Mianyang, Deyang, Chengdu, and Guangyuan, 140 counties (cities or districts), 3,765 villages (towns). The population of the disaster area was 70.6715 million, with 20.4164 million households, and the total affected population was 46.24 million.

Table 9 Areas severely affected by the Wenchuan Earthquake

Impact	Province	County (City or District)
Very severely hit county (city) (10)	Sichuan (10)	Wenchuan County, Beichuan County, Mianzhu City, Shifang City, Qingchuan County, Mao County, An County, Dujiangyan City, Pingwu County, and Pengzhou City
Severely hit county (city or district) (36)	Sichuan (26)	Li County, Jiangyou City, Lizhou District, Chaotian District, Wangcang County, Zitong County, Youxian District, Jingyang District, Xiaojin County, Fucheng District, Luojiang County, Heishui County, Chongzhou City, Jiange County, Santai County, Yanzhong City, Yanting County, Songfan County, Cangxi County, Lushan County, Zhongjiang County, Yuanba District, Dayi County, Baoxing County, Nanjiang County, and Guanghan City
	Gansu (7)	Wen County, Wudu District, Kang County, Cheng County, Hui County, Xihe County, and Liangdang County
	Shaanxi (3)	Ningqiang County, Lueyang County, and Mian County

Data source Earthquake Relief Experts Group of National Committee for Disaster Reduction and Ministry of Science and Technology (2008)

4.2 Emergency Rescue Process

On the day of the Wenchuan Earthquake, the then Premier of the State Council, Wen Jiabao, immediately flew to the disaster area, set up the Earthquake Relief Headquarters and started the national emergency response I. On 17 May 2008, the President and General Secretary of the Central Committee of the Communist Party of China, Hu Jintao, urged at the disaster area that local governments, militaries, and all rescue forces should unify the leadership and command; in particular to strengthen coordination between military and civilian forces and formed a mechanism of vigorous collaboration and close cooperation, to carry out relief work orderly.

On 19 May 2008, with the overall progress of rescue work, the State Council adjusted and improved the composition and structure of the Earthquake Relief Headquarters of the State Council (Table 10). Under the unified command of the Earthquake Relief Headquarters, an earthquake relief campaign with the fastest speed, most broad mobilization, and greatest input in the Chinese history was launched, maximizing life-saving of disaster victims and minimizing disaster losses. A total of 84,017 people were rescued from ruins and 1.49 million people trapped in collapsed buildings were saved. More than 4.3 million sick and injured people received timely treatment and over 10 thousand patients were quickly transferred to 375 hospitals of over 20 provinces and cities. A total of 0.146 million People’s Liberation Army soldiers and armed police officers as well as 75 thousand

Table 10 Composition and structure of the Earthquake Relief Headquarters of the State Council

Commander in Chief		Wen Jiabao
Vice Commander in Chief		Li Keqiang and Hui Liangyu
Emergency rescue and disaster relief team	Leading unit	General Staff Headquarters of the People's Liberation Army
	Member unit	Ministry of Public Security, Safety Supervision Bureau, China Earthquake Administration, People's Armed Police Force, and Chengdu Military Region
Public affairs team	Leading unit	Ministry of Civil Affairs
	Member unit	Ministry of Foreign Affairs, National Development and Reform Commission, Ministry of Finance, Ministry of Housing and Urban-Rural Development, Ministry of Commerce, Ministry of Agriculture, and Red Cross
Earthquake monitoring team	Leading unit	China Earthquake Administration
	Member unit	Ministry of Science and Technology, Ministry of Land and Resources, Ministry of Environmental Protection, China Meteorological Administration, and Administration for Science, Technology and Industry for National Defense
Hygiene and disease control team	Leading unit	Ministry of Health
	Member unit	National Development and Reform Commission, Ministry of Agriculture, General Administration of Quality Supervision, Inspection and Quarantine, Food and Drug Administration, General Logistics Department of the People's Liberation Army, and People's Armed Police Force
Communication team	Leading unit	Publicity Department of the Central Committee of the Communist Party of China
	Member unit	Ministry of Foreign Affairs, State Administration of Radio, Film and Television, Office of Taiwan Affairs, News Office of the State Council, Office of Hong Kong and Macao Affairs, and China Meteorological Administration
Production recovery team	Leading unit	Ministry of Industry and Information Technology
	Member unit	National Development and Reform Commission, Ministry of Finance, Ministry of Commerce, Ministry of Human Resources and Social Security, Ministry of Agriculture, State-owned Assets Supervision and Administration Commission, Safety Supervision Bureau, China Insurance Regulatory Commission, and Administration for Science, Technology and Industry for National Defense
Infrastructure recovery and post-disaster reconstruction team	Leading unit	National Development and Reform Commission
	Member unit	Ministry of Industry and Information Technology, Ministry of Civil Affairs, Ministry of Finance, Ministry of Housing and Urban-Rural Development, Ministry of Transport, Ministry of Railways, Ministry of Agriculture, State-owned Assets Supervision and Administration Commission, State

(continued)

Table 10 (continued)

Commander in Chief		Wen Jiabao
Vice Commander in Chief		Li Keqiang and Hui Liangyu
		Administration of Radio, Film and Television, Safety Supervision Bureau, China Banking Regulatory Commission, State Electricity Regulatory Commission, Post Bureau, Civil Aviation Administration, and State Grid Corporation of China
Water conservancy team	Leading unit	Ministry of Water Resources
	Member unit	National Development and Reform Commission, Ministry of Finance, Ministry of Land and Resources, Ministry of Environmental Protection, Ministry of Housing and Urban-Rural Development, Ministry of Health, Ministry of Agriculture, China Earthquake Administration, China Meteorological Administration, State Electricity Regulatory Commission, and Operations Department of the Headquarters of the General Staff of the People's Liberation Army
Social security team	Leading unit	Ministry of Public Security
	Member unit	Ministry of Education, Ministry of Justice, People's Bank of China, China Banking Regulatory Commission, China Securities Regulatory Commission, Tourism Administration, State Bureau for Letters and Calls, and People's Armed Police Force
Experts Committee	Leading unit	Ministry of Science and Technology, Ministry of Education, Ministry of Land and Resources, Ministry of Water Resources, China Earthquake Administration, Chinese Academy of Sciences, Chinese Academy of Engineering, Chinese Academy of Geological Sciences, and China Academy of Building Research

Data source The State Council (2008)

reserve militia-men and women participated in disaster rescue, and the whole nation was mobilized to vigorously support the disaster relief efforts.

As of 25 September 2008, the Ministry of Civil Affairs allocated and transported totally 1.5797 million makeshift tents, 4.8669 million blankets, 14.1013 million clothes, 4.146 million tons of fuel oil, and 8.858 million tons of coal; a total of 677,131 prefabricated houses (movable plank houses) was installed in the earthquake affected areas. Governments at all levels provided totally RMB 80.936 billion Yuan funds for earthquake emergency rescue and disaster relief. Financial input of the central government amounted to RMB 73.457 billion Yuan, wherein RMB 33.132 billion Yuan was used for emergency rescue and relief and RMB 40.325 billion Yuan was used for post-disaster reconstruction. Financial input of local governments was RMB 7.479 billion Yuan.

4.3 Disaster Response Mechanism

Information release mechanism: Only 12 min after the Wenchuan Earthquake, the short-message quick report system of the China Earthquake Administration sent out the three earthquake parameters (time, location, and earthquake magnitude) to the relevant staff and members of earthquake rescue teams. At the same time, formal documents about detailed earthquake occurrence information were also reported to the State Council. Upon receiving the Wenchuan Earthquake information, News Media such as the China Central Television (CCTV) rapidly released the news to the nation. Through the development over decades, earthquake information release mechanism of China made great progress and the general public receives earthquake information within a short time after earthquake occurrence. On the second day after the earthquake, the State Council made a decision that all Wenchuan Earthquake-related information should be released by the News Office of the State Council to guarantee consistency and accuracy of the information. Rumors were avoided with open and transparent information release mechanism, and this not only stabilized disaster victims' mood, but also gained support of world opinion, thus speeding up emergency rescue as well as restoration and reconstruction work.

Comprehensive coordination mechanism: In accordance with the deployment of the Central Committee of the Communist Party of China, the State Council and Central Military Commission, under the unified command and coordination of the State Council Earthquake Relief Headquarters, each ministry and commission of the State Council, local governments, military, armed police force, volunteers, and other forces coordinated with each other and carried out emergency rescue and reconstruction efficiently, orderly, and quickly through work division and cooperation. Soon after the earthquake, China mobilized the People's Liberation Army, armed police force, public security police, fire police, and special police (a total of more than 20 professional branches and 150,000 people), as well as 75 thousand reserve militias, and organized 5,257 professional rescue members, and 91.3 thousand medical treatment and public health members. The central financial department arranged relief funds timely, and China Earthquake Administration and other functional departments including civil administration, health, public security, water, education, and transportation launched emergency plans and emergency response actions and developed emergency rescue and other arrangements immediately. Across the country, the public showed great solidarity and made tremendous efforts to support the disaster areas, for example through organizing emergency rescue teams, supplying goods and materials, treating the injured, building temporary and transition shelters, among others. Provinces and cities outside the disaster areas developed counterpart assistance arrangements with the disaster areas; governments of Hong Kong and Macao Special Administrative Regions dispatched helicopters and service teams, rescue teams, infectious disease prevention teams, and medical treatment teams to Sichuan for earthquake relief works; they also raised funds to support the reconstruction of the disaster areas.

Nationwide-mobilization for disaster response mechanism: Through the Wenchuan Earthquake disaster response, China demonstrated its unprecedented national strength, concentrated its military capacity, and achieved great solidarity of the people. Wenchuan Earthquake disaster relief also fully reflected the advantages of the Chinese system in making concerted effort for major undertakings. The Wenchuan Earthquake disaster relief experience shows that the centralized leadership structure of the Chinese system is highly beneficial for reducing decision conflicts in crisis situation and is conducive to forming coordinated actions in national disaster relief; the centralized Chinese administrative system is highly beneficial for ensuring the government to mobilize and integrate various emergency rescue and disaster relief forces, gather resources, and maximally improve the effectiveness of the government's emergency response in crisis situation; the Chinese military system of central command is highly conducive to rapidly mobilize armed forces that act as the main force and the commando in responding to natural catastrophes. Therefore, in future major disaster situations, it is necessary to fully take advantage of the unique Chinese governance system, optimize the leadership system and working mechanism, and further develop the unique Chinese mechanisms for responding to major disasters (Shi and Liu 2009).

4.4 Restoration and Reconstruction

Formulation of restoration and reconstruction policies: Facing the huge losses of collapsed and damaged buildings, damaged infrastructure, and industrial and agricultural production and ecological environment destructions due to the catastrophe, under the leadership of the General Headquarters of Earthquake Rescue and Relief the government made a comprehensive and rapid assessment of the disaster situation, formulated reconstruction plans according to the law, and established a national counterpart assistance mechanism for rapid disaster recovery and reconstruction. On 4 June 2008, the State Council approved the *Regulation on Post-Wenchuan Earthquake Restoration and Reconstruction* (hereinafter referred to as the *Regulation*), which was issued and implemented on 8 June 2008. This is the first law on post-disaster restoration and reconstruction in the history of China in coping with large disasters. The issues of temporary sheltering and resettlement of displaced disaster victims, investigating and assessing disaster losses, developing restoration and reconstruction plans and implementation, fund-raising and policy support for recovery, supervision and management, and legal responsibilities were addressed in the *Regulation*, which laid a solid legal foundation for restoration and reconstruction (Table 11).

According to the *Regulation* and based on the rapid scientific assessment of the Wenchuan Earthquake disaster impact, the central government promulgated a series of plans and policies, including “Directive on Counterpart Assistance for Post-Wenchuan Earthquake Restoration and Reconstruction” on 11 June 2008, “Suggestions on Post-Wenchuan Earthquake Restoration and Reconstruction” on

Table 11 Post-Wenchuan Earthquake restoration and reconstruction policy documents

Time of issuance and implementation	Policy documents
8 June 2008	Regulation on Post-Wenchuan Earthquake Restoration and Reconstruction
11 June 2008	Directive on Counterpart Assistance for Post-Wenchuan Earthquake Restoration and Reconstruction, State Council
29 June 2008	Suggestions on Post-Wenchuan Earthquake Restoration and Reconstruction, State Council
3 July 2008	Guiding Opinions on Post-Wenchuan Earthquake Restoration and Reconstruction
19 September 2008	Overall Plan for Post-Wenchuan Earthquake Restoration and Reconstruction
October–November 2008	Special Plans for Post-Wenchuan Earthquake Restoration and Reconstruction
In and after September 2008–	Plans for Post-Wenchuan Earthquake Restoration and Reconstruction, approved by various regional governments

29 June 2008, “Guiding Opinions on Post Wenchuan Earthquake Restoration and Reconstruction” on 3 July 2008, and the “Overall Plan on Post Wenchuan Earthquake Restoration and Reconstruction” on 19 September 2008 as the policy framework for the catastrophe recovery.

The “Overall Plan on Post Wenchuan Earthquake Restoration and Reconstruction” (Overall Plan) identified the basic principles, objectives, and contents for recovery. It required to invest RMB 1,000 billion Yuan within about 3 years through local government fund allocation, counterpart assistance, public donations, domestic bank loans, capital market financing, foreign emergency loans on favorable terms, urban and rural residents private capital, capital of enterprises, and innovation financing, for earthquake restoration and reconstruction in the 51 significantly affected counties. The objective was to provide housing for all families, ensure employment for households of working population, provide security for each person, improve infrastructure, ensure development in economy, and realize improvement in ecology. The basic living conditions and economic development should reach or surpass the pre-disaster levels. Endeavor to build a new homeland characterized by enjoyable life and work, eco-civilization, security, and harmony, and lay a solid foundation for sustainable socioeconomic development.

In order to achieve the objectives of the Overall Plan and to rationally allocate resources, the central government proposed the “counterpart assistance” mechanism, under which each of 19 individual provinces (municipalities) and Shenzhen Special Economic Zone supported one significantly affected county on a one-on-one basis (Table 12, except that Tianjin Municipality supported two major disaster counties in Shaanxi Province and Shenzhen supported four major disaster counties in Gansu Province) by committing 1 % of the local financial revenue in the preceding year for goods and operation costs every year for three consecutive years. Enterprises, social groups, and individuals in various regions were also encouraged

Table 12 Counterpart assistance arrangement for Post-Wenchuan Earthquake restoration and reconstruction

ID	Supporting area → Supported area	ID	Supporting area → Supported area
1	Shandong Province → Beichuan County, Sichuan Province	11	Shanxi Province → Mao County, Sichuan Province
2	Guangdong Province → Wenchuan County, Sichuan Province	12	Hunan Province → Li County, Sichuan Province
3	Zhejiang Province → Qingchuan County, Sichuan Province	13	Jilin Province → Heishui County, Sichuan Province
4	Jiangsu Province → Mianzhu City, Sichuan Province	14	Anhui Province → Songpan County, Sichuan Province
5	Beijing Municipality → Shifang City, Sichuan Province	15	Jiangxi Province → Xiaojin County, Sichuan Province
6	Shanghai Municipality → Dujiangyan City, Sichuan Province	16	Hubei Province → Hanyuan County, Sichuan Province
7	Hebei Province → Pingwu County, Sichuan Province	17	Chongqing Municipality → Chongzhou City, Sichuan Province
8	Liaoning Province → An County, Sichuan Province	18	Heilongjiang Province → Jiange County, Sichuan Province
9	Henan Province → Jiangyou City, Sichuan Province	19	Shenzhen → Wen County, Kang County, Cheng County, Wudu District of Longnan City, Sichuan Province
10	Fujian Province → Pengzhou City, Sichuan Province	20	Tianjin Municipality → Ningqiang County and Lueyang County in Shaanxi Province

Data source Directive on Counterpart Assistance for Post-Wenchuan Earthquake Restoration and Reconstruction, State Council, 11 June 2008

to invest for starting factories and constructing then operating infrastructures in disaster areas in accordance with the market rules.

In order to further ensure the successful implementation of the Overall Plan and accelerate the restoration and reconstruction process, the National Development and Reform Commission (NDRC) and relevant government departments issued the Special Planning for Urban and Rural Housing Construction in Post-Wenchuan Earthquake Restoration and Reconstruction Project; Special Planning for Cities and Towns System in Post-Wenchuan Earthquake Restoration and Reconstruction Project; Special Planning for Rural Construction in Post-Wenchuan Earthquake Restoration and Reconstruction Project; Special Planning for Public Service Facilities Construction in Post-Wenchuan Earthquake Restoration and Reconstruction Project; Special Planning for Infrastructure Facilities Construction in Post-Wenchuan Earthquake Restoration and Reconstruction Project; Special Planning for Productive Force Distribution and Industrial Adjustment in Post-Wenchuan Earthquake Restoration and Reconstruction Project; Special Planning for Market Service System in Post-Wenchuan Earthquake Restoration and Reconstruction Project; Special Planning for Disaster Prevention and Reduction in Post-Wenchuan Earthquake Restoration and Reconstruction Project;

Special Planning for Ecology Restoration in Post-Wenchuan Earthquake Restoration and Reconstruction Project; and Special Planning for Land Use in Post-Wenchuan Earthquake Restoration and Reconstruction Project successively in October and November 2008, and presented specific objectives and tasks of reconstruction in relevant fields, thus extending and refining the objectives and tasks of the Overall Plan in specific areas (Shi et al. 2012).

Considering the rapid progress of reconstruction in the disaster areas, in March 2009, the Second Session of the Eleventh National People's Congress proposed that the scheduled 3-year reconstruction tasks can be completed in 2 years, that is, complete the tasks specified in the Overall Plan before September 2010.

Implementation of restoration and reconstruction: By May 2011, a total of RMB 1020.5 billion Yuan had been invested in restoration and reconstruction, therein, the central government financial department invested RMB 302.6 billion Yuan. At this point, all national reconstruction projects of disaster areas in Sichuan, Shaanxi, and Gansu had been started; the completed projects accounted for 95 % of all projects; and completed investment took up 95 % of the total investment. The housing conditions of urban and rural residents had been remarkably improved. Within one year after the earthquake, the restoration and reinforcement of damaged houses had been completed; within one and a half years after the earthquake, the reconstruction of rural housing had been totally completed; and within two years after the earthquake, housing reconstruction in cities and towns had been largely completed. In the disaster areas, in the three (Sichuan, Shaanxi, Gansu) provinces 2.92 million rural houses and 1.46 million houses in cities and towns were reinforced and repaired; and 1.91 million rural houses and 290 thousand houses in cities and towns were reconstructed. The public service facilities had been largely improved. Damaged schools and hospitals were fully restored and reconstructed. Furthermore, a large number of social welfare institutions, elderly homes, community service centers, activities center for rural residents, and other public service facilities had also been built. The earthquake fortification standard of schools and hospitals had been increased from 7 to 8. So the buildings became stronger and safer, and the facilities and devices were improved significantly.

On the whole, the focus of the planned projects and investments were mainly on securing the basic safety of disaster victims, infrastructure construction, productive capacity deployment, and industrial readjustment. Investment in disaster prevention and reduction was relatively little.

Summary of the restoration and reconstruction experiences: **Counterpart assistance mechanism** has played an important role in restoration and reconstruction. After the Wenchuan Earthquake, under the unified resource deployment of the Central Committee of the Communist Party of China, the counterpart assistance arrangement organized related provinces and municipalities to provide assistance to the disaster areas in order to speed up post-disaster restoration and reconstruction. The implementation of the “one province assists one hard-hit county” policy demonstrated the strength of the Chinese socialist system and fully mobilized the resource of the whole nation—it became a platform for gathering the forces for restoration and reconstruction, integrating various resources, bridging the

financing gaps in post-disaster reconstruction, providing supports in manpower, materials, and intelligence and helped the disaster areas resolve a large number of urgent problems with regard to people's livelihood, and laid a firm foundation for the long-term development of the disaster areas. In addition, a supervision mechanism for the use of reconstruction funds was created and plans for funds allocation and use were formulated. The funds were well used and the use efficiency was improved, which enabled the implementation of various reconstruction projects. The counterpart assistance arrangement had clearly defined tasks. Through strengthening regional cooperation with provinces (municipalities) that provide counterpart assistance, their resource advantages (location, industry, capital, and others) were fully tapped into. Restoration and reconstruction of residential buildings, agriculture and rural infrastructures, especially in poor areas, were carried out by means of non-disaster areas assisting disaster areas and developed areas assisting undeveloped areas. Through strengthening the regional economic cooperation, the "blood transfusion" function of assistance was transformed into "hematopoiesis" function for local economic development; short-term assistance was changed into long-term economic development measures to promote the adjustment of regional industrial structures, industrial development, and the cooperation and communication among regions, and bring advanced concepts, opening-up channels and communication channels, advanced technology and markets, and so on, thus gradually driving the economic restoration and development of the disaster areas.

In combination with the construction of small towns and poverty alleviation programs, this has laid a solid foundation for the construction of new socialist countryside. The rural restoration and reconstruction after the earthquake disaster are directly related to not only the rural production and living of the rural population, but also the long-term development of the economy and society of the disaster areas and have been integrated with the small town construction and poverty alleviation programs. First, the restoration and reconstruction have paid attention to the coordination of rural living and rural production and properly handled the relationship between living and production development to realize a peaceful life and ensure that all people have houses to live, land to farm, and a secured livelihood in the new villages. Secondly, the restoration and reconstruction have focused on the coordination of reconstruction and region development and appropriately handled the relationship between current and long-term developments, integrated the post-disaster restoration and reconstruction of rural areas with strengthening region development and balancing urban and rural developments, rationally and scientifically determined the direction and objective of development, and focused on the post-disaster restoration and reconstruction and new countryside development pilot projects for demonstration. Thirdly, the restoration and reconstruction have paid attention to the integration of uniformed planning and local characteristics/practices, properly handled the relationship between safe living and economical and practical designs, performed village and farmhouse reconstruction as per the geographical, industrial, and ethnic features of the local areas, realized the integration between seismic resistance and disaster prevention and between uniformed planning and local characteristics and practically, and well managed the relationship between safe

living and development with local characteristics. Fourthly, the restoration and reconstruction have emphasized the integration of reconstruction and ecological restoration, and have paid great attention to the relationship between development and protection and creating a harmonious ecological environment. Lastly, the restoration and reconstruction have emphasized the integration between self-aid of rural residents and government subsidy and social assistance, mobilized all resources, and taken into consideration the interest of all stakeholders to carry out the difficult tasks in post-disaster restoration and reconstruction. According to the surveys, with respect to post-earthquake restoration and reconstruction, especially in rural housing and infrastructure, the new developments in some areas have exceeded the level before the earthquake and reached a higher stage as compared to the plans. This has also laid a foundation for accelerating the new socialist countryside construction locally.

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