

Meta-synthesis pattern of post-disaster recovery and reconstruction: based on actual investigation on 2008 Wenchuan earthquake

Jiuping Xu · Yi Lu

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Abstract A devastating Ms8.0 earthquake struck Wenchuan on May 12, 2008, a historical county in Sichuan Province, southwest China, which affected more than half of China. This article makes a comparative study on the pre-earthquake prevention and post-earthquake reconstruction of 14 world-famous earthquakes in the last 100 years, generalizes the various problems in the process of recovery and reconstruction and analyzes the reasons for the enormous damage caused by these earthquakes. Through theoretical research and field investigation on post-Wenchuan earthquake recovery and reconstruction, the meta-synthesis pattern has been summarized and developed. Its ideological foundation is meta-synthesis methodology, concrete expression is Wuli–Shili–Renli three-dimensional approach, and practical realization using an integrated framework. Taking post-earthquake recovery and reconstruction as a complicated systematic project, from the vertical perspective, the whole process can be roughly divided into the phases of transitional recovery and comprehensive reconstruction. While from the horizontal perspective, each phase should have its own support systems. From an investigation of the systematic planning and comprehensive implementation, it can be concluded that post-Wenchuan earthquake recovery and reconstruction has made remarkable achievements over the past 3 years. Since disasters continue to threaten humanity around the world, especially climate-induced extreme weather events, other countries could formulate applicable integrated programs for post-disaster recovery and reconstruction, taking the Wenchuan experience as a reference.

Keywords Wenchuan earthquake · Meta-synthesis pattern · Transitional recovery · Comprehensive reconstruction · Support systems

1 Introduction

The Wenchuan Ms8.0 earthquake occurred at 14:28 on May 12, 2008 in Southwest China's Sichuan Province, seriously striking over 20 counties (cities) in Sichuan Province,

J. Xu (✉) · Y. Lu

Uncertain Decision-making Laboratory, Sichuan University, Chengdu 610064, China
e-mail: xujiuping@scu.edu.cn

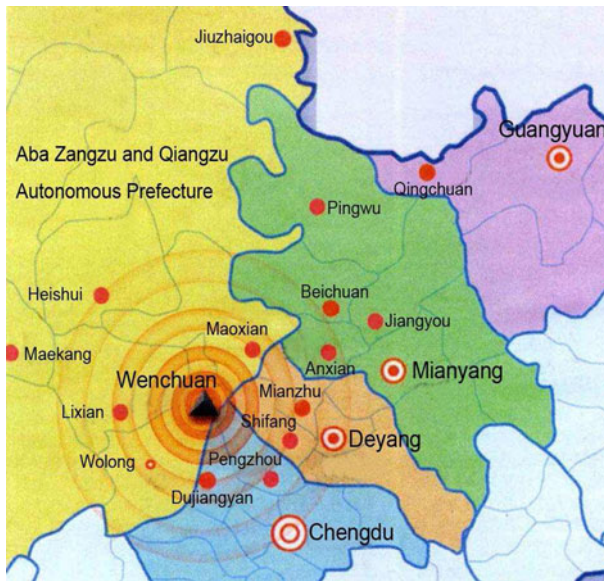


Fig. 1 The distribution of 2008 Wenchuan earthquake

such as Beichuan, Wenchuan, Mianzhu, Qingchuan, Shifang, Dujiangyan, Pingwu, Anxian, Jianguyou, Pengzhou, Maoxian, Lixian, Wolong, Chengdu, Deyang, Mianyang, and Guangyuan (Fig. 1), spreading to Gansu, Shanxi, Chongqing, Yunnan Provinces, and Municipalities. As China's worst natural disaster since the Tangshan earthquake, the 2008 Wenchuan earthquake affected more than half of China, covering a total area of approximately 500,000 km² (Klinger et al. 2010; Cao and Kamel 2011); with at least 15 million people being evacuated from their homes, and more than 5 million becoming homeless (Zhao et al. 2009). According to statistics, the Wenchuan earthquake left 87,000 people dead or missing and caused direct economic losses of about US\$ 130 billion (Gao 2011; Wang 2011).

Normally, there are three major stages in coping with serious natural disasters: rescue and relief, recovery, and reconstruction (Alexander 2000). Though the Wenchuan earthquake posed great difficulties and challenges, the Chinese government successfully completed the unprecedented earthquake rescue and relief task by mobilizing the resources of the entire Chinese society and with the support and aid of the international community (UNDP 2009). However, there are important issues concerning the stages of recovery and reconstruction. The disaster areas of the Wenchuan earthquake are mainly situated in the transitional area from the Qinghai-Tibet Plateau to the Sichuan Basin with the Longmen Mountains as the dividing line, the geological and topographical features between the west and the east are quite different from each other (Cui et al. 2011), as is socioeconomic development level. The affected areas were home to many ethnic minority groups, including China's only concentrated area of the Qiang ethnic group and one of the major Tibetan settlement areas. In general, the post-Wenchuan earthquake recovery and reconstruction (PWERR) has been extremely strenuous and challenges, confronted with the difficult situations of such a widely disaster-affected area, such a large quake-effected population, such severely damaged infrastructure, as well as complex social and natural conditions.

A lot of research on the subject of post-earthquake recovery and reconstruction (PERR) has been conducted. Hirayama (2000) and Kamel (2004) introduced the recovery and reconstruction of housing after earthquakes in Kobe and Northridge. Hanes (2000) investigated the problems of urban planning after the earthquake in Kanto, Japan. Sonak et al. (2008) proposed an integrated coastal zone management concept for environmental reconstruction after the 2004 earthquake-triggered tsunami in India. Ghafory-Ashtiany and Hosseini (2008) explained the recovery and reconstruction of housing and infrastructure in Bam earthquake. Omidvar et al. (2010) examined reconstruction policies post-Bam earthquake, such as financial policies and construction technology policies. Although meticulous research on PERR had been done in these studies, few gave specific directions on PWERR. An integrated strategy therefore is required to promote the implementation of PWERR in an orderly and efficient manner (Sun and Xu 2011).

The Chinese government has paid great attention to PWERR. The State Council Post-Earthquake Reconstruction Office (SCPERO) was established following the earthquake. On Jun. 8 2008, the State Council approved Regulations on Post-Wenchuan Earthquake Rehabilitation and Reconstruction, the first regulation formulated for PERR in China. On Aug. 12, 2008, the State Overall Plan for Post-Wenchuan Earthquake Restoration and Reconstruction was released. On Oct. 4, 2008, the State Council established a Group for Coordinating Recovery and Reconstruction in place of the Earthquake Relief Headquarters (Dunford and Li 2011). Additionally, the government invited experts in various fields to participate in PERR, which has also made significant contributions to the smooth recovery and reconstruction of quake-hit areas.

The corresponding author was elected as a member of Specialists Service Groups on Sichuan Post-earthquake Recovery and Reconstruction for his outstanding achievements on post-disaster recovery and reconstruction. Since May 14, 2008, 2 days after the earthquake, the corresponding author established a research team and carried out intense investigation into the disaster areas, and submitted a series of reports on PERR to the SCPERO and Sichuan Provincial government. A meta-synthesis pattern of post-earthquake reconstruction was originally proposed to instruct the PWERR 2 months after the earthquake (Xu and Lu 2008).

This article summarizes and improves the meta-synthesis pattern of post-disaster recovery and reconstruction based on an investigation of the 2008 Wenchuan earthquake in the 3 years of the PERR's progress. Firstly, we studied 14 world-famous earthquakes by studying the seismic disaster factors and the lessons learned from PERR. And analysis, a meta-synthesis pattern, comprised of meta-synthesis methodology, WSR three-dimensional approach, and an integrated framework, was developed. Based on this meta-synthesis pattern, the transitional recovery and comprehensive reconstruction processes and measures as well as the support systems of PWERR are comprehensively discussed.

2 Comparative analysis

From the research on pre-earthquake prevention and post-earthquake reconstruction, many useful experiences for a better PERR can be garnered to develop better hazard mitigation and disaster preparedness. Tables 1 and 2 show the basic data, natural factors, and disaster statistics of 14 largest earthquakes in the world since 1990.

From Tables 1 and 2, a strong earthquake causes significant damage to a many regions and sectors, which can cause difficulties in the implementation of PERR. Despite the main determinants of hazard level should be natural factors (e.g., magnitude, focal depth, and

Table 1 Basic data and natural factors of 14 world's famous earthquakes

Nation	Epicenter	Time	Natural factors		
			Magnitude (x_1)	Focal depth (x_2)	Epicenter intensity (x_3)
Haiti	Port au Prince	2010.01.13	Ms 7.0	10 km	X
China	Wenchuan	2008.05.12	Ms 8.0	19 km	XI
Indonesia	Sumatra coast	2004.12.26	Ms 9.0	27 km	XII
India	Gujarat	2001.01.26	Ms 7.9	15 km	IX
El Salvador	Pacific Rim	2001.01.13	Ms 7.6	60 km	IX
China	Nantou, Taiwan	1999.09.21	Ms 7.6	8 km	X
Turkey	Izmit	1999.08.17	Ms 7.4	33 km	IX
Japan	Osaka-Kobe area	1995.01.17	Ms 7.2	17 km	XI
America	Northridge, California	1994.01.17	Ms 7.1	18 km	IX
Armenia	Leninakan	1988.12.07	Ms 7.1	18 km	X
Mexico	Coastal Michoacan	1985.09.19	Ms 8.1	33 km	XI
China	Tangshan	1976.07.28	Ms 7.8	11 km	XI
Japan	Tokyo-Yokohama area	1923.09.01	Ms 8.3	10 km	XI

epicenter intensity), human factors yet can not be ignored. According to statistics of 14 earthquakes, the human factors, including inferior lifeline engineering, weak disaster prevention awareness, poor quality buildings, incomplete emergency information systems, ineffective building codes enforcement, weak government emergency measures, imperfect disaster prevention system, low seismic fortification criterion, poor rescue techniques and equipment, unreasonable urban planning, high population density, irrational building structure, and serious environmental damage are also closely related to seismic disasters (Table 3).

To investigate the relationship between seismic disaster and trigger factors, the following variables and symbols are used. Seismic disasters are considered dependent variables, encompassing such factors as affected regions, casualties, and economic loss, marked as y_1 , y_2 , and y_3 (Table 2). The independent variables include both natural and human factors, with natural factors being magnitude, focal depth, and epicenter intensity, marked as x_1 , x_2 , and x_3 (Table 1), and human factors marked as x_4 to x_{16} (Table 3).

From experience, the following correlation functions are determined:

$$y_1 = f_1(x_1, x_2, x_3)$$

$$y_2 = f_2(x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11}, x_{12}, x_{13}, x_{14}, x_{15}, x_{16})$$

$$y_3 = f_3(x_1, x_2, x_3, x_4, x_6, x_8, x_{11}, x_{13}, x_{14}, x_{15}, x_{16})$$

When seismic disasters occur, there are many factors affecting the severity (Fig. 2). Of these, the affected region (y_1) is mainly determined by the natural properties of the earthquake, such as the magnitude, the focal depth, and the epicenter intensity (i.e., x_1 , x_2 and x_3). Casualties and economic losses, however, are not only closely related to the natural factors, but also are affected by human factors. Almost all the factors listed in Table 3 affect the number of casualties (y_2), such as previous poor construction quality (i.e., x_4 , x_6 , x_8 , x_{11} and x_{15}), weak emergency response systems (i.e., x_7 , x_9 , x_{10} and x_{12}), low disaster prevention awareness (x_5), and unfocused urban planning and development

Table 2 Disaster statistics of 14 world’s famous earthquakes

Nation	Disaster statistics		
	Affecting regions (y_1)	Number of casualties (y_2)	Economic loss (y_3)
Haiti	Most areas of the country	Over 200 thousand killed and 300 thousand injured	8 billion USD
China	Affecting half of China	About 79 thousand killed and 374 thousand injured	130 billion USD
Pakistan	Most parts of Pakistan and some parts of India	About 87 thousand killed and 200 thousand injured	10 billion USD
Indonesia	Several countries in Southeast Asia	About 300 thousand killed	50 billion USD
India	The whole Gujarat	Over 20 thousand killed and 150 thousand injured	5 billion USD
El Salvador	The whole Caribbean	About 1 thousand and 4.7 thousand injured	10 billion USD
China	West Taiwan area	About 2 thousand killed and 8.5 thousand injured	13 billion USD
Turkey	Northwest Turkey	About 14 thousand killed and 27 thousand injured	20 billion USD
Japan	The whole Kobe region	About 5.4 thousand killed and 34 thousand injured	100 billion USD
America	The entire Los Angeles	73 killed and nearly 10 thousand injured	20 billion USD
Armenia	The whole Leninakan and spreading to Georgia	About 25 thousand killed and 12 thousand injured	20 billion USD
Mexico	Mexico City and states in Western Pacific coast	About 12 thousand killed and 20 thousand injured	5 billion USD
China	The whole Tangshan	About 242 thousand killed and 164 thousand injured	20 billion USD
Japan	Throughout Tokyo, Yokohama and Yokosuka	Over 100 thousand killed and 200 thousand injured	3 billion USD

(i.e., x_{13} , x_{14} , and x_{16}). In conclusion, all natural and human factors (from x_1 to x_{16}) have influence on casualties (y_2). Of these, emergency systems and disaster prevention awareness concentrate on the disaster resilience of the people, and economic losses (y_3), which in turn are mainly related to natural factors, poor construction quality, and irrational urban planning and development (i.e., x_1 , x_2 , x_3 , x_4 , x_6 , x_8 , x_{11} , x_{13} , x_{14} , x_{15} and x_{16}). In PERR, these negative factors need to be avoided.

From a study of the world-famous earthquakes in PERR, the difficulties are summarized as follows:

- (1) Housing and infrastructure: emergency shelters and temporary housing, the construction of permanent housing, the quality of rebuilt buildings.
- (2) Economic system: market turmoil, costly resumption of production, difficulties in enterprise and industrial reconstruction.
- (3) Social system: psychological restoration, the orphan dependency, rebuilding families, community reconstruction, special geographical and national culture preservation.

Table 3 The statistics of human factors triggering the huge damage of 14 earthquakes

Human factors	E ₁	E ₂	E ₃	E ₄	E ₅	E ₆	E ₇	E ₈	E ₉	E ₁₀	E ₁₁	E ₁₂	E ₁₃	E ₁₄
Inferior lifeline engineering (x ₄)	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	
Weak disaster prevention awareness (x ₅)	✓	✓	✓	✓	✓			✓	✓		✓		✓	✓
Poor quality buildings (x ₆)	✓	✓	✓		✓		✓	✓		✓	✓	✓		
Incomplete emergency information systems (x ₇)	✓		✓	✓	✓	✓	✓	✓	✓		✓		✓	
Ineffective building codes enforcement (x ₈)	✓	✓	✓		✓		✓	✓		✓	✓			
Weak government emergency measures(x ₉)	✓		✓		✓			✓	✓		✓		✓	
Imperfect disaster prevention system (x ₁₀)	✓		✓	✓	✓	✓			✓		✓			
Low seismic fortification criterion (x ₁₁)	✓		✓						✓			✓	✓	
Poor rescue techniques and equipment (x ₁₂)	✓		✓		✓			✓			✓			
Unreasonable urban planning (x ₁₃)	✓				✓					✓		✓		✓
High population density (x ₁₄)	✓		✓		✓							✓	✓	
Irrational building structure (x ₁₅)	✓		✓						✓	✓				✓
Serious environmental damage (x ₁₆)						✓						✓		

E₁: Haiti, E₂: Wenchuan, China, E₃: Pakistan, E₄: Indonesia, E₅: India, E₆: El Salvador, E₇: Taiwan, China, E₈: Turkey, E₉: Kobe, Japan, E₁₀: America, E₁₁: Armenia, E₁₂: Mexico, E₁₃: Tangshan, China, E₁₄: Kanto, Japan

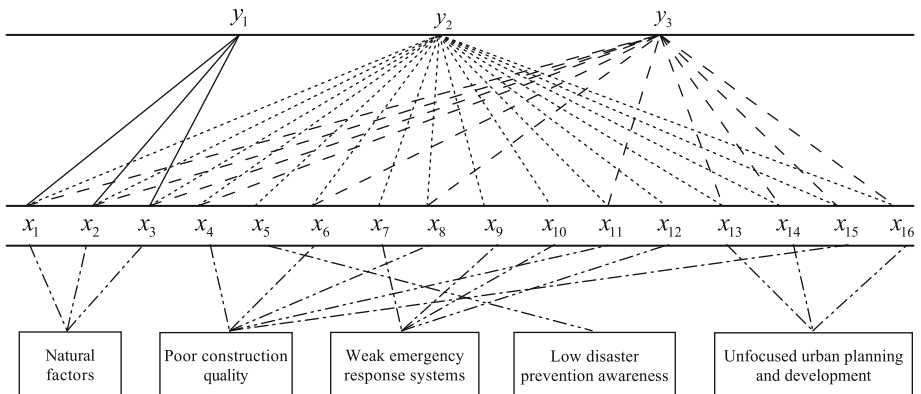


Fig. 2 Related factors in earthquake damage and their classification

- (4) Ecological system: secondary disasters, reconstruction location selection, eco-environment restoration, cultivated land reclamation.
- (5) Policy and law: the adjustment of policies for the financial, fiscal, taxation, land, industrial and other systems in the PERR process, and disaster relief legislation.

The above issues are related to multiple aspects including the economy, society, politics, legislation, culture, and nature. As a general approach is unable to consider these issues systematically, this article, based on theoretical research and an investigation of an actual PWERR case, proposes the meta-synthesis pattern for the guidance of PERR.

3 Meta-synthesis pattern

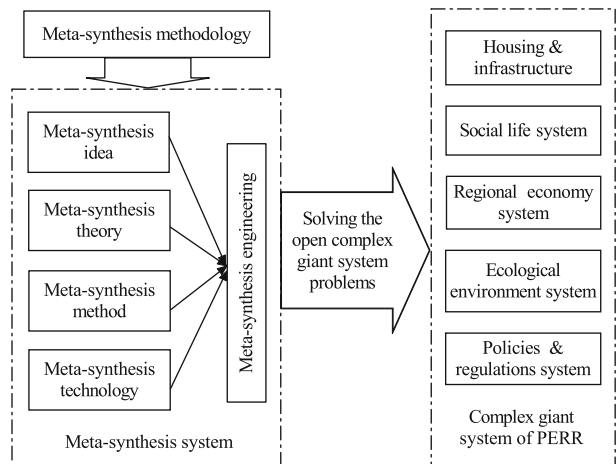
The meta-synthesis pattern is a special mode of China’s PERR, which ideological foundation is meta-synthesis methodology, concrete expression is WSR three-dimensional approach, and practical realization using an integrated framework. A brief definition of the meta-synthesis pattern is overall consideration, systematic planning, and comprehensive implementation.

3.1 Meta-synthesis methodology

Meta-synthesis is an important representation of oriental systems methodologies to deal with system complexities (Pressman 1992), which overcomes the limitations of western analytical thinking when dealing with the unstructured problems of quantitative modeling. In the early 1990s, Professor Qian Xuesen (Tsien HsueShen), known as the father of China’s space and missile programs, proposed the meta-synthesis approach for solving open complex giant system problems, which emphasized the synthesis of collected information and expert knowledge and combined quantitative methods with qualitative knowledge (Gu and Tang 2005). The PERR system is composed of a series of intertwined and interrelated subsystems, such as, housing and infrastructure, social life, regional economy, ecological environment, and policies and regulations, which are organized and managed by a meta-synthesis system, which consists of meta-synthesis idea, meta-synthesis theory, meta-synthesis method, meta-synthesis technology, and meta-synthesis engineering, as shown in Fig. 3.

For the meta-synthesis system, the meta-synthesis idea emphasizes the dialectical unity of Holism and Reductionism, and the full integration of macro- and micro-research studies, which generally regard PERR as a complex system, while deeply analyzing the systemic

Fig. 3 Meta-synthesis methodology of PERR



structure and organizational operation. Meta-synthesis theory employs a multiple angles approach when analyzing PERR problems with multi-disciplinary theories, such as the contradiction between high-speed socioeconomic development and low-speed ecological restoration. The meta-synthesis method aims to solve PERR problems using a combination of qualitative and quantitative methods, such as the integration of operations research methods and sociological survey methods in social life restoration. Meta-synthesis technology uses technology solutions for both reasonable technical and economic measures to address PERR problems. Finally, meta-synthesis engineering integrates the meta-synthesis idea, theory, method and technology to solve the PWERR systematic project problems.

3.2 WSR three-dimensional approach

The Wuli–Shili–Renli (WSR) approach is a systematic method based on oriental culture, and a special evolvement of meta-synthesis methodology (Gu and Zhu 2000). PERR is a dynamic unity of WSR, in which, Wuli refers to natural laws or scientific principles, such as the laws of earthquake resulting geohazards, the rules of building earthquake resistance, and the objective challenges during PERR; Shili refers to operational measures, such as the processes and approaches needed for a comprehensive assessment of seismic disasters, overall PERR planning, and the collaborative implementation of PERR; Renli refers to human nature, such as the respect for people’s requirements and the coordination of society and nature during PERR. While, Hall’s three-dimensional morphology of systems engineering is a systematic method based on occidental culture (Hall 1969), which investigates complex engineering problems in a three-dimensional structure composed of Professional dimension, Time dimension, and Logic dimension. A WSR three-dimensional approach, integrating both oriental and occidental system thinking, is proper to solve complex systemic problem. A system construction is shown in Fig. 4.

Wuli, Shili, and Renli, as the coordinate axes of a three-dimensional structure system, are the systematic and integrated critical factors that are considered during the process of PERR. Firstly, Wuli corresponds to the professional dimension, that is, PERR has to be

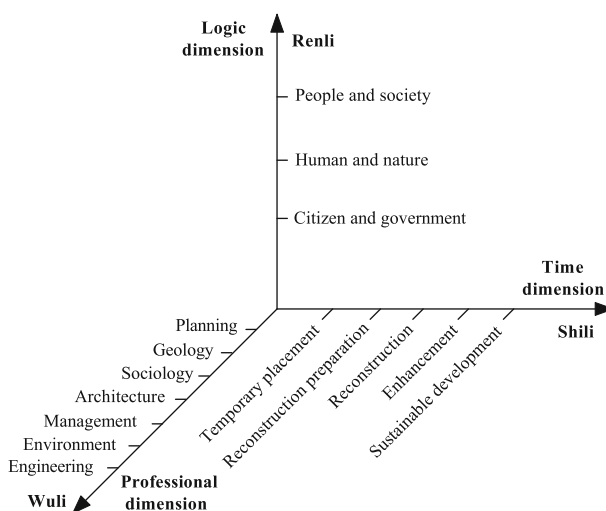


Fig. 4 WSR three-dimensional approach of PERR

scientific and thus is based on planning, geology, sociology, architecture, management, the environment, engineering, and other professional disciplines. Secondly, Shili corresponds to the time dimension, that is, PERR takes scientific evaluation as its premise, which ensures an orderly implementation according to scientific planning. Thirdly, Renli corresponds to the logic dimension, that is, PERR must have as its main goal the requirements of the affected people and rationalizes the relationship between the people and society, humans and nature, and citizens and the government.

According to the State Overall Plan for Post-Wenchuan Earthquake Restoration and Reconstruction, the principles of PWERR are People oriented, Nature respected, Overall planning, and Scientific reconstruction (Planning Committee of PWERR 2008), in which, People oriented, Nature respected, and Overall planning correspond to Renli, Wuli, and Shili, respectively. However, to implement a scientific reconstruction, an integrated framework is essential.

3.3 Integrated framework

Based on an actual investigation and theoretical support from meta-synthesis methodology and the WSR three-dimensional approach, the integrated framework of PERR is constructed as shown in Fig. 5. From the vertical perspective, the complete PERR process is roughly divided into two phases: transitional recovery and comprehensive reconstruction. The former may last days to months, at which time the situation is partly returned to normal; the latter lasts months to years, at which time the region is fully returned to normal (World Bank 2008). In the transitional recovery phase, temporary placement and reconstruction preparation are carried out concurrently, constituting the prerequisites and the basis for comprehensive reconstruction. Because comprehensive reconstruction requires a

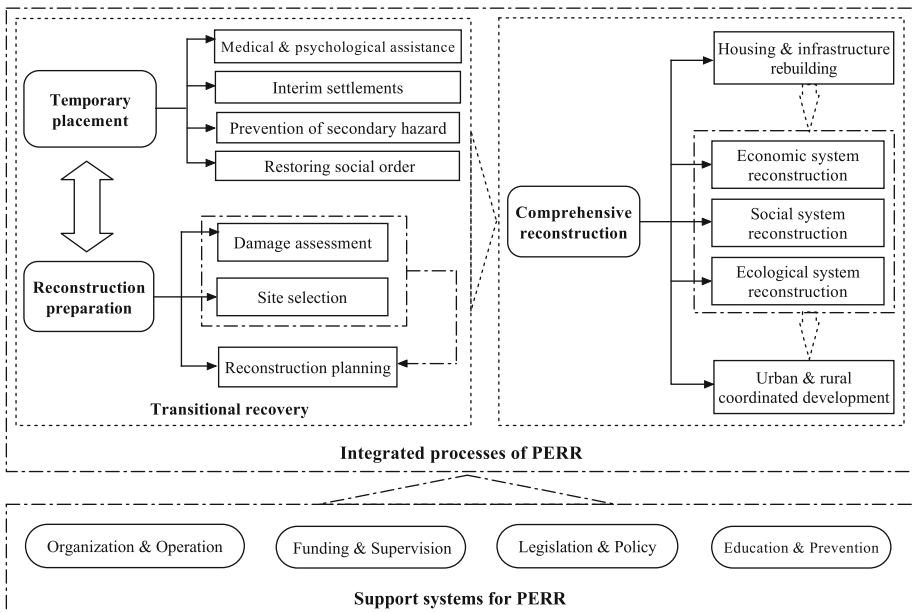


Fig. 5 Integrated framework of PERR

long time, it is divided into three levels. The first level is to rebuild facilities, i.e., high-quality reconstruction of housing and infrastructure; the second level is to enhance comprehensive capabilities, i.e., systematic reconstruction of the economic, social, and ecological systems; the third level is to achieve sustainable development, i.e., the coordinated development of urban and rural areas. On the horizontal, each PERR program has support systems, such as organizational and operational systems, funding and supervision systems, legislation and policy systems, and education and prevention systems, which also play a significant role in the PERR's progress.

Through a series of projects on PWERR, such as the Emergency Program of National Natural Science Foundation of China, the Major Bidding Program of National Social Science Foundation of China, and the Investigation Propaganda Department of China Association for Science and Technology, the corresponding author and his research team engaged in field observations and interviews in the most serious quake-stricken counties and cities in Sichuan Province, such as Wenchuan, Beichuan, Qingchuan, Dujiangyan, Guangyuan, and Mianyang and paid close attention to the progress of PWERR through information sources such as newspapers, networks, and television. According to the field research and comprehensive observation, the meta-synthesis pattern has been applied in PWERR. The application of meta-synthesis pattern's methodology, approach, and integrated framework is detailed below.

4 Transitional recovery

According to the meta-synthesis pattern, the large, complex tasks of transitional recovery need to be systematically considered and concurrently promoted within the overall arrangement of all available forces (e.g., governments, experts, NGOs, and social workers) and resources (e.g., medicines, tents, and donations). Temporary placement is those social and natural activities (e.g., medical and psychological assistance, interim settlements, secondary hazard prevention, and social order restoration) that take place within weeks to months after the earthquake. Also occurring at the same time during this phase is preparation for the reconstruction phase.

4.1 Temporary placement

Temporary placement is a critical transitional period focussing on the immediate rescue efforts and is also the first step of PERR. The task of this phase is to give the survivors a basic survival condition. Based on the overall consideration of Wuli–Shili–Renli in post-disaster recovery, the post-Wenchuan earthquake temporary placement process was designed and implemented (Fig. 6).

4.1.1 Medical and psychological assistance

In the Wenchuan earthquake, medical and psychological assistance was the first and critical step following the successful rescue and relief operations. From a preliminary assessment of the number of physically injured and psychologically damaged, sufficient medical staff and psychology volunteers were organized or self-organized to disaster areas. More than 370,000 were injured in the Wenchuan earthquake, with a large number of survivors needing urgent medical assistance. During the first 2 weeks after the disaster, thousands of medical workers and NGOs flooded into the disaster areas by all available

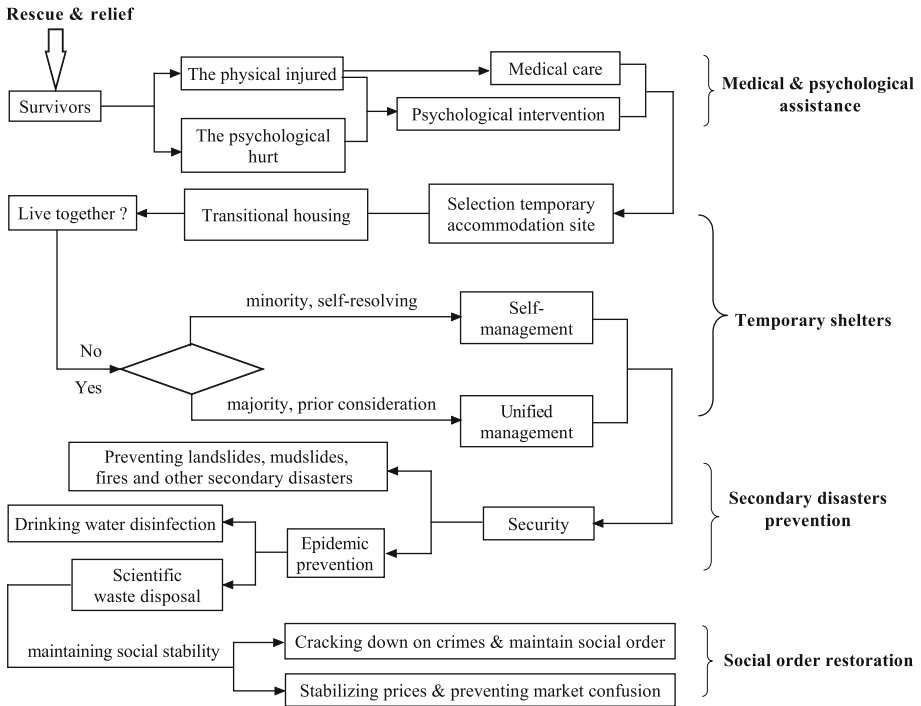


Fig. 6 Procedures of temporary placement

transport means. The injured were transferred to the nearby hospitals by automobiles, planes, and helicopters. The governments committed to the establishment of a provisional medical and health services to meet people’s basic medical needs. Compared with physical injuries, psychological trauma was more difficult to heal, possibly causing even greater harm (Xu and Wu 2011; Xu and Song 2011). Within a month, more than 2,000 psychology volunteers went to affected regions. They performed psychological interventions to assist survivors overcome the psychological problems caused by the crisis and through timely psychological counseling reduced the negative social impact of the disaster.

4.1.2 Interim settlements

Interim settlements should be immediately available and sent to affected areas after the disaster, which is essential for a quick recovery of the population and to allow time for better reconstruction (Johnson 2007). The decisions on interim settlements, therefore, should consider a set of requirements, such as society, safety, the environment, and adequate funding (El-Anwar et al. 2009). By gathering and analyzing the displaced families data and the characteristics of alternative locations, the government and specialists determined the program of interim settlements and resettled tens of millions of affected people. Because unified transitional housing is convenient for construction and management, centralized resettlement was preferred to accommodate the affected population. One month after the earthquake, thousands of tents were transferred to the affected areas; and 2 months after that, the tents had been mostly replaced by portable housing. At the same

time, permanent housing was designed and allowing most of people to move into new houses by the end of 2008.

4.1.3 Secondary hazard prevention

The Wenchuan earthquake caused a series of secondary geological hazards, such as landslides, barrier lakes, and debris flows, and sharply increased the possibility of epidemic disease. Secondary hazards generally last several months or even years (the terrible debris flow in Aug 2010 is an example) and can significantly affect the success of recovery and reconstruction efforts. The longer-term secondary hazard issue requires continuous and sustained professional efforts. The state council therefore established the Secondary Disaster Prevention Expert Group on National Wenchuan Earthquake Reconstruction to address the threat of secondary hazards. With the support of experts, governments undertook a massive operation to deal with the challenges. The temporary resettlement areas all had emergency measures, such as geological monitoring, disaster warning, and fire prevention. Local governments also strengthened epidemic control and improved sanitation and epidemic prevention systems. Disinfection was regularly carried out in all housing projects in the affected areas. The first Epidemic Prevention Laboratory, set up in Maoxian County, was in operation within 2 weeks after the Wenchuan earthquake.

4.1.4 Social order restoration

The restoration of social order is the major goal of transitional recovery; a healthy social order is the foundation of a smooth comprehensive reconstruction. There were a number of destabilizing factors post-Wenchuan earthquake, such as theft, robbery, market confusion, and prices rises, which disrupted the social order of the affected areas. In order to restore social order, rectify social security and prevent market confusion, local governments committed to stabilize the market supply and restore schools, offices, and finance. By the end of July 2008, 60% of the commercial networks had been resumed, and most of the governmental departments were back to normal. Besides, a lot of social workers participated in the PWERR. Though there were many difficulties in providing disaster assistance, social workers performed valuable services and made a significant contribution to the restoration of social order.

4.2 Reconstruction preparation

Reconstruction preparation is the concurrent engineering of temporary placement, which is the foundation of successful reconstruction. Damage assessment was the initial step to ascertain the range and emphasis of reconstruction and proposed advice toward PWERR plans. Site selection was a critical step in determining the ideal reconstruction location. Reconstruction planning, the final step, offered essential and comprehensive guidance for the PWERR (Fig. 7).

4.2.1 Damage assessment

A comprehensive damage assessment leading to the identification of recovery and reconstruction needs is essential for ascertaining the range and emphasis for the reconstruction (Xu and Lu 2009). On May 21, 2008, the Earthquake Relief Headquarters of the

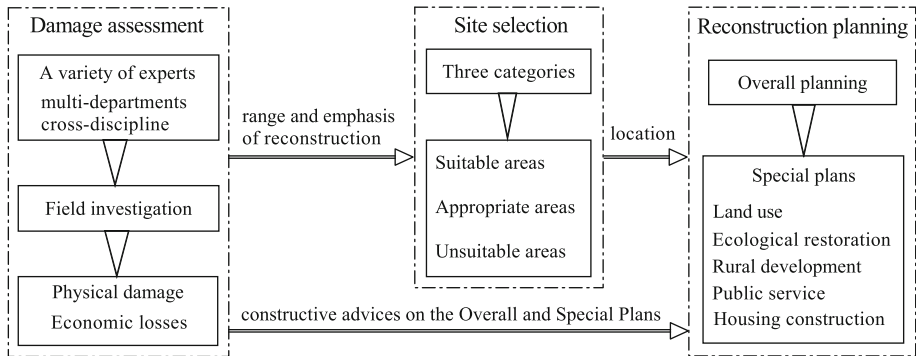


Fig. 7 Steps of reconstruction preparation

State Council set up the National Wenchuan Earthquake Expert Committee (NWEEC), made up of 30 experts. To complete the complicated task, the experts were recommended by the China Earthquake Administration, the Ministry of Science and Technology, and the Ministry of Land and Resources, according to the principles of multi-departmental cooperation and cross-disciplines. After its establishment, NWEEC immediately coordinated with the field investigation and research team to investigate the physical damage and assess the economic losses. Over the 3 months’ investigation, using of remote sensing data and local statistics, the NWEEC developed the final conclusion, which contributed constructive advice to the Overall and Special Plans for PWERR (Shi 2008).

4.2.2 Site selection

Site selection is an extremely important aspect of PWERR. Because the earthquake caused a further deterioration of the already fragile geological environment, there were significant potential risks in the reconstruction of damaged towns (Huang et al. 2009). The site, once selected is very difficult to change later because of the fixedness of buildings, and also it is necessary to consider whether it is conducive to future long-term development. Based on a comprehensive evaluation of the resources and environment carrying capacity, and in accordance with the appropriateness of population aggregation, urban construction, and industry development direction, the national land in the affected areas was divided into three categories: suitable for reconstruction; appropriate for reconstruction; and unsuitable for reconstruction. The relocation of Beichuan County, the only autonomous county for the Qiang ethnic group of China, is a prominent example of a place that was unsuitable for reconstruction. As the old county had been greatly destroyed, and there was no suitable site available for reconstruction, a serious debate was undertaken on the selection of a new site for Beichuan county. Through demonstration and advice integration, the new county seat of Beichuan was located about 23 km south of the old county seat, and a new Beichuan was reestablished after 2 years.

4.2.3 Reconstruction planning

Post-earthquake reconstruction planning is a scientific and systematic decision, which needs to consider not only the current needs, but also needs to comprehensively arrange for sustainable long-term regional development for the affected areas. For the Wenchuan

earthquake, after over 4 months of field research and expert discussion, the overall planning and a series of special plans were produced to guide post-earthquake reconstruction. Specifically, the overall planning was focused on general requirements, spatial distribution, urban and rural housing, public services, industrial reconstruction, and policies and measures. The special plans then involved productivity distribution and industrial restructuring, land use, market service system, ecological restoration, rural development, public service facilities, and urban and rural housing construction. In this respect, the reconstruction planning was consistent with the idea of meta-synthesis and ensured that the quake-hit areas would be rebuilt in a scientific, orderly and efficient way.

5 Comprehensive reconstruction

According to the PERR integrated framework, comprehensive reconstruction is composed of housing and infrastructure rebuilding, economic, social and ecological systems reconstruction, and urban and rural coordinated development. The principles and approaches of Wuli, Shili, and Renli are considered for each part. In practice, comprehensive reconstruction after the Wenchuan earthquake adhered to the laws of nature (i.e., Wuli), abided by reconstruction planning (i.e., Shili) and improved the relationship between short-term reconstruction and long-term development (i.e., Renli).

5.1 Housing and infrastructure rebuilding

Housing and infrastructure system reconstruction is the primary duty of reconstruction and the foundation of economic, social, and ecological system reconstruction. The rebuilding of housing and infrastructure needs to abide by Wuli (i.e., follow the principles of seismic-resistant design and environmentally friendly construction), consider Renli (i.e., the rebuilt facilities must be better than the destroyed for the affected population) and acknowledge Shili (i.e., meet modern standards and implement according to plan).

5.1.1 Housing rebuilding

The housing rebuilding during PWERR pursued harmony between people and nature by appropriate planning and arrangement. After the Wenchuan earthquake, over 5 million families lost their houses; therefore, rebuilding permanent housing was an urgent task for the affected people placed in the temporary shelters. According to the “Special Plan for Wenchuan Earthquake Restoration and Reconstruction of Urban and Rural Housing Construction”, jointly issued by National Development and Reform Commission, Housing and Urban-Rural Development Ministry, and Civil Affairs Ministry on Nov 2008, the housing rebuilding program was planned to basically be completed within 2 years. According to comparative analysis in the second section, poor quality construction was the main cause of casualties and property losses. To overcome this problem, shortly after the earthquake, the Chinese government strictly enforced the requirements for seismic fortification, rigorously implemented national construction standards and technical specifications and strictly controlled the quality of design, construction and building materials. Note that, the idea of green reconstruction was carried out throughout PWERR. Helped and trained by local governments and construction experts, the affected families rebuilt their housing using disaster-resistant techniques and environmentally friendly materials. Waste

materials collected from quake-destroyed buildings were used to develop warm, fire-proof and quake-proof building materials.

5.1.2 Infrastructure rebuilding

A successful reconstruction program should support not only the reconstruction of housing units but also of adequate public infrastructure (e.g., transportation, communications, energy, and water) and social infrastructure (e.g., hospitals, public spaces, schools, and shops), which contribute to the improvement of living conditions for the affected communities. The Wenchuan earthquake seriously damaged the infrastructure system of quake-hit areas, such as highways, railways, bridges, electricity and communications networks, water reservoirs and other infrastructure elements. Reconstruction is a unique opportunity for the upgrading of critical infrastructure. According to the “Special Plan for Wenchuan Earthquake Restoration and Reconstruction of Infrastructure” published by the National Development and Reform Commission on Nov 2008, the infrastructure reconstruction would take 3 years. Based on the plan, efforts were made to bring conditions to full capacity. Combined with the rebuilding of infrastructure came the creation of job opportunities through the public works programs, providing affected families with new income-earning paths.

5.2 Economic system reconstruction

According to the meta-synthesis methodology, economic, social, and ecological systems were integrated into the complete multiplexed system using correlation and interaction during PWERR. The reconstruction of the economic system, which is mainly comprised of enterprise redevelopment and industry rejuvenation, provided financial support for the reconstruction of the social and ecological systems (Fig. 8). Economic system reconstruction is more concerned with Shili, for instance, how to deal with the different difficulties of key enterprises and small- and medium-sized enterprises, how to adjust industrial distribution, revitalize traditional industries and develop new industries.

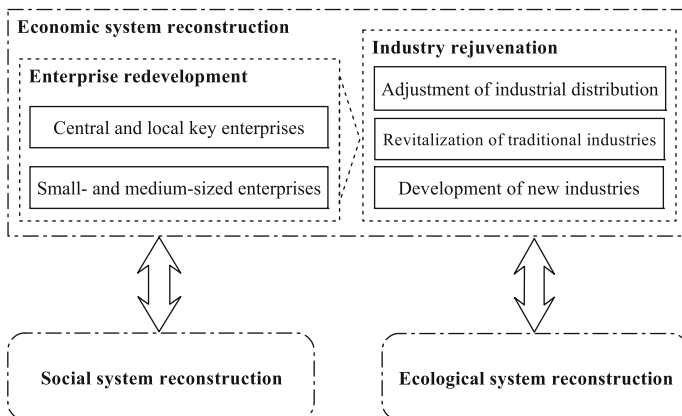


Fig. 8 The framework of economic system reconstruction

5.2.1 Enterprise redevelopment

Enterprises are the cells of the economic system, and enterprise redevelopment is the basis for economic system reconstruction. In order to stabilize the post-earthquake economic system, various kinds of enterprises were accorded preferential policies. Central and local key enterprises were given special and prior treatment to support their restoration and reconstruction. Further, by providing such support, these enterprises by expanding employment, producing necessities, and serving reconstruction, allowed the small- and medium-sized enterprises (main component of private sector) to be given adequate support. A series of policies focused on support for the redevelopment of disaster-affected enterprises by developing plans for expanding industry scales, raising production levels, and enhancing profiles. A majority of enterprises (especially those with independent intellectual property rights or independent innovation) received relief from favorable compensation policies, including tax policies, financial policies, and land policies. Furthermore, preferential policies were also accorded to enterprises which created job opportunities for affected people.

5.2.2 Industry rejuvenation

A great deal of attention was paid to the rejuvenation of industry. Many government departments (e.g., National Development and Reform Commission, Ministry of Industry and Information Technology, and the Sichuan Provincial Government) jointly promulgated the “Special Plan for Wenchuan Earthquake Restoration and Reconstruction of Productivity Distribution and Industrial Restructuring” on Nov 2008. According to the plan, the reasonable adjustment of industrial distribution, the revitalization of traditional industries, and the development of new industries were the main focuses for the enhancement of the post-earthquake economic system. First, national and provincial development zones were enlarged, such as in the high-tech industrial zones in Chengdu and Mianyang; the industrial parks were merged and relocated, such as the Beichuan Stone Material Industrial Park and the Qingchuan Industrial Clusters. Second, distinctive competitive industries were cultivated and expanded based on the economic characteristics of local area, with full attention being paid to hydropower development, mining resources, animal husbandry, agriculture and other natural advantages. Third, as the eco-environment was seriously destroyed, low-carbon industries (e.g., renewable resources industry, the culture industry, and high-tech industries) were promoted, and circular economic industry cluster districts established to reduce environmental damage.

5.3 Social system reconstruction

The reconstruction of the social system consists of people rehabilitation, family rebuilding, and community reestablishment. With people as the critical components of family and community, social system reconstruction focusses on Renli, such as providing affected people with medical services, psychological consultations, and employment assistance, and assisting the older people, orphans, widows, widowers, and parents who had lost children to form new families and communities. The goal of economic and ecological system reconstruction is to improve the livelihood of disaster areas and to engage the local people in economic and ecological system reconstruction (Fig. 9).

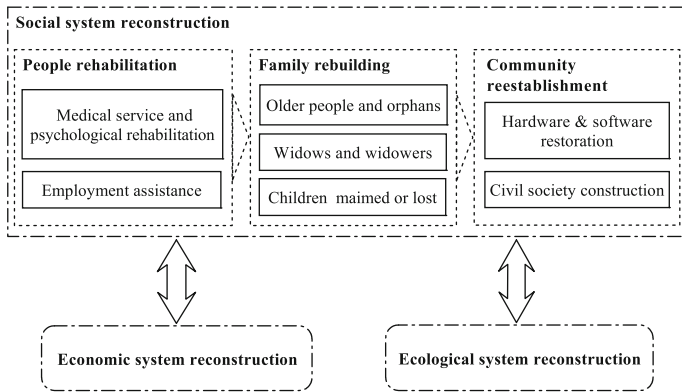


Fig. 9 The framework of social system reconstruction

5.3.1 People rehabilitation

The first principle of PWERR is “people oriented”, indicating that the Chinese government has paid high attention to people rehabilitation, as it is the start and basis of social system reconstruction. At the beginning of social reconstruction, the local governments established a population registration and indication system to resolve housing, employment, education, health care, and pension issues, as well as to provide other assistance and support for the affected population. Medical service and psychological rehabilitation public welfare programs were implemented especially for the disabled or people suffering long-term trauma. More than 20 rehabilitation centers have been built since the earthquake occurred, allowing disabled people to return to normal life and reintegrate into their communities. Besides, having to face physical and psychological hurt, people’s livelihood was severely affected. Only with employment for the affected population, could the people have rehabilitation fully realized. By a “Work for the Dole” scheme and the implementation of preferential policies, local governments provided the unemployed and the disabled with job opportunities.

5.3.2 Family rebuilding

The family is the basic unit of society, and rebuilding enhances social confidence in the affected areas. A large number of families were no longer complete after the Wenchuan earthquake, so the government and society faced challenges in helping affected families with separated older people, orphans, widows, widowers, and parents who had lost children. In this case, the governments, assisted by warmhearted families as well as professional social workers and doctors, implemented many measures to rebuild affected families. First, the governments built social welfare institutions, which could, to some extent, enable older people and orphans to enjoy the warmth of a big family with attentive care from social workers. Second, families with professional nursing skills and psychological assistance skills were encouraged to adopt orphans, and hundreds of orphans got new families. Third, widows or widowers, whose spouses were victims of the earthquake, were encouraged to form new families. Finally, the Chinese government supported those parents who lost children in the earthquake by providing both financial assistance and policy initiatives, including a fertility assistance program (Qin et al. 2009). With doctors’ professional help from the region, many of the families who had lost children started new families.

5.3.3 Community reestablishment

The community is a microcosm of society, providing a relatively stable and comfortable living environment for people and family. After the Wenchuan earthquake, thousands of communities across urban and rural areas needed to be reestablished. The reestablishment of communities' hardware and software was paid attention to. New communities with comprehensive and convenient public service facilities were built in cities, towns, and central villages. Also, several further actions, such as the reconstruction of cultural facilities, and promoting the spirit of quake rescue and relief were taken to accelerate community cultural renewal. More importantly, the incipient civil society initiatives were widely praised. Residents with high prestige or good organizational skills were selected to the self-managed community organizations, which protected the participation and supervision rights of community members. Furthermore, the huge demand for public services during community reestablishment allowed grassroots social organizations to establish. Both domestic and international NGOs have played a solid role in the wider area of community reconstruction and development since the earthquake.

5.4 Ecological system reconstruction

In respect for natural laws and scientific principles (i.e., Wuli), socioeconomic development is underpinned by progress in ecological system reconstruction. The scientific reconstruction of the economic and social systems therefore needs to fully consider the available resources and the environment carrying capacity, and the lengthy period needed for the region to recover its ecological function. The ecological system reconstruction was implemented in consideration of land protection, ecological restoration, and environmental improvement with the purpose of promoting a coordinated development of population, resources and the environment (Fig. 10).

5.4.1 Land protection

Land is not only the basic element of the ecosystem, but also the most important natural resource for economic and social reconstruction. The earthquake ruined a great deal of cultivated land in Sichuan, a major agricultural province in China. A failure to protect

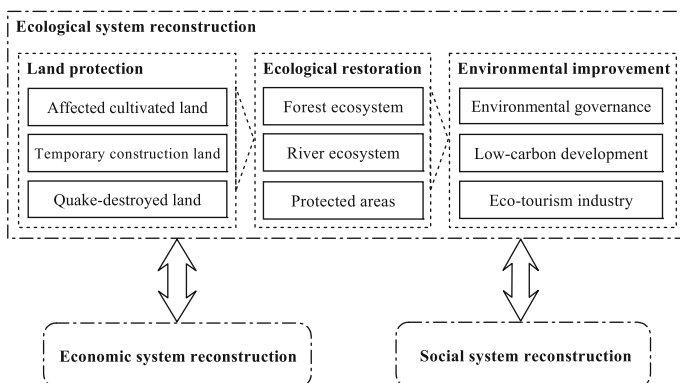


Fig. 10 The framework of ecological system reconstruction

farmland could harm the region's ecosystems and affect further socioeconomic development. From the scientific evaluation, the land of the quake-hit areas was divided into three categories: affected cultivated land, temporary construction land, and quake-destroyed land. Measures were carried out to protect and restore land resources. First, several policies were published to promote the reclamation of cultivated land, especially basic farmland. Second, temporary construction land used for transitional settlements was restored to arable land as the affected population moved into permanent housing, so as to minimize farmland losses. Third, the quake-destroyed land, such as the original sites of the damaged towns, villages, industries and mines, are planned for ecological restoration to ensure sustainable land use.

5.4.2 Ecological restoration

Ecological restoration is a critical step. The Wenchuan earthquake buried vast areas of forest, destroyed river ecosystems, and disrupted the habitats of pandas and golden monkeys, so it was estimated that full restoration would take decades to rehabilitate naturally (Stone 2009). Ecological restoration focused on forests, rivers and protected areas. First, the reform of forest property rights system was further advanced to ensure natural forest conservation and the conversion of cropland to forest. Second, many ecological rehabilitation projects focusing on the affected rivers were implemented to gradually restore the river's ecological functions, such as provision of water and soil conservation. Third, priority was given to the restoration of special protected areas, such as nature reserves, scenic spots, forest parks, and geological parks at all levels. In particular, the giant panda habitat in Wolong was seriously damaged, and its restoration was paid attention to by the whole world (Deng et al. 2010).

5.4.3 Environmental improvement

Even though the eco-environment was destroyed by the Wenchuan earthquake, the environmental improvement is not only for its restoration, but also to promote the sustainable development of the population, society, and the economy. Environmental governance is a basic measure for improvement of the environment. Consequently, the monitoring and administration of pollution sources and environmentally sensitive areas were enhanced to reduce environmental pollution during PWERR. Many cities and counties in the disaster areas have drawn up and carried out low-carbon development planning, with the governments dedicated to creating favorable living environments and economic patterns in accordance with the resource carrying capacity. A good eco-environment can also bring significant income. Sichuan is rich in eco-tourism resources, because of its unique natural conditions and successful ecological restoration. World Heritage sites (e.g., Wolong panda habitat and the Dujiangyan water conservancy) attract many visitors, benefiting the long-term development of the tourism industry in the affected areas.

5.5 Urban and rural coordinated development

As the affected region is an integration of both urban and rural areas, according to the meta-synthesis idea, the goal of PWERR is indeed to achieve a coordinated development urban and rural regions. Since the primary disaster area in Sichuan is located in the Chengdu, Deyang, and Mianyang economic belt, which have a better economic base, and

Chengdu and Deyang are, respectively, the national and province-level coordinating urban and rural comprehensive reform experimental area, the PWERR actually provides the affected area with an opportunity to explore the coordination of urban and rural coordinated development. Urban and rural comprehensive reform and new rural construction are the two significant themes in the progress of PWERR. Combined with the implementation of the Chinese Western Development Strategy, the governments developed a comprehensive reform plan for the urban and rural systems. According to the plan, the integration of urban and rural public service facilities, cultural and educational resources, and health and social security systems was gradually promoted, so as to push the comprehensive development of the affected region’s economic, social and ecological systems. New rural construction is indeed an essential measure to achieve urban and rural coordinated development. In the rural communities, housing and living facilities were rebuilt at a high standard to ensure the development of an environmentally friendly countryside. The industrialization and automation of agricultural production was also paid attention to, which helped to promote the urbanized development of rural areas.

6 Support systems for PWERR

Obviously, PWERR is a complicated systematic project, thus support systems, such as organizational and operational systems, funding and supervision systems, legislation and policy systems, and education and prevention systems, are indispensable components in the integrated framework of PWERR and have played a significant role in the progress of PWERR.

6.1 Organization and operation

As a complex systems engineering system, PWERR depends on strong organizational support, including central governments, local governments, counterpart governments, NGOs, media, experts, volunteers, and the public. During a practical operation, the particular organizational system of “government guidance, public participation” is an important guarantee for the successful implementation of PWERR (Fig. 11).

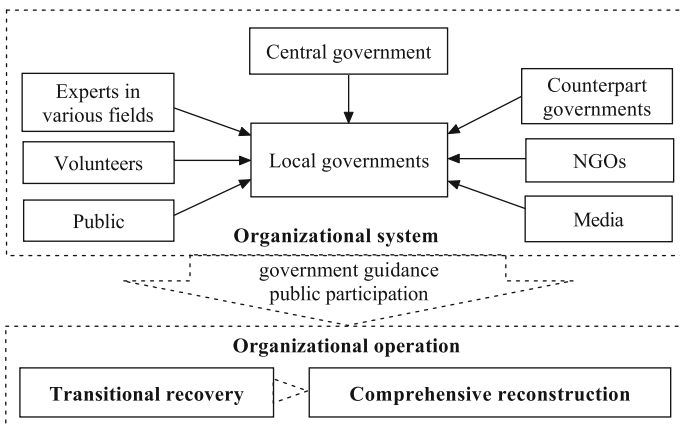


Fig. 11 The organizational system of PWERR

In the PWERR organizational system, local governments were in charge of the overall operation in the affected areas, e.g., coordinating various organizations, gathering relief resources and promoting reconstruction progress. Central government departments, including the State Council and subordinate Civil Affairs, Finance, Industry, and other departments, were responsible for the compilation and implementation of policies and regulations to provide financial and policy supporting for PWERR. Counterpart governments have had a positive effects on the PWERR work in severely affected counties (cities, districts) providing manpower, material, and financial support. As to the social forces, the NGOs played a significant role in resources integration, health care, psychological intervention, and community services; the media enhanced civil supervision on large PWERR projects; experts in various fields proposed constructive suggestions and guided the implementation of PWERR; volunteers and the public provided a full range of diversified public goods, including physical, psychological, and security for the affected population. Consequently, all participants played essential roles in promoting PWERR.

6.2 Funding and supervision

The lengthy PWERR process requires prolonged and sufficient funding. It is estimated that the total demand for PWERR funds is 1 trillion yuan (over US\$ 1,500 billion). Thus, the establishment of funds collection channels and supervision of funds allocation and use is an extremely important task for PWERR. In addition to the central government's 3,000 billion yuan PWERR funds, financing has been carried out using a multi-channel approach, including mainly local government investment, counterpart government support, social donations, domestic bank loans, and foreign emergency loans. The funds were prioritized for rebuilding housing, infrastructure and basic public facilities, and providing social welfare. To ensure the reasonable allocation and use of funds, strict supervision was enforced by establishing monitoring mechanisms. As the funds were large and coming through various channels, and needed to be allocated across a very wide range of services, the central government set up a "clearing account" in respect of the collection, allocation, and use of the funds. Strict cadre assessment and accountability was practiced in order to prevent officials embezzling relief materials and funds. Therefore, most of the reconstruction funds have been reasonably used, and corruption has rarely occurred.

6.3 Legislation and policy

Legislation and Policy are the most powerful weapons in PWERR and have provided guidance and support for the transitional recovery and comprehensive reconstruction. Above all, it is necessary to ensure the process of PWERR under legislation. "Regulations on Post-Wenchuan Earthquake Rehabilitation and Reconstruction" was the first Chinese specific regulation for a local PERR, laying the cornerstone for a legitimate PWERR (The State Council 2008). This regulation defines the relevant guidelines and principles for PWERR, and makes clear requirements and provisions on such aspects as transitional settlements, disaster assessment, financing and policy support. The regulation has also clarified the legal liabilities for violations, providing a good institutional environment for PWERR. A good use of aid policies can also improve the regional socioeconomic development capacity and make a significant contribution to PWERR. The "Policies and Measures of State Council support on Post-Wenchuan Earthquake Reconstruction" was promulgated on June 2008 by the State Council, formulating appropriate fiscal, monetary, industrial, social and other preferential policies to support PWERR. The "Program of

Post-Wenchuan Earthquake Restoration and Reconstruction Counterpart Support” issued on June 2008 is an initiative of PWERR promoting counterpart support for 3 years 18 provinces (municipalities) in the east and central region, the 18 most seriously affected counties (cities, districts).

6.4 Education and prevention

The governments and the public believe that the Wenchuan earthquake tragedy should be the turning point for China to move toward a more disaster resilient future. The specific ways to achieve this target is mainly by enhancing public disaster prevention awareness and strengthening governmental disaster prevention systems. It is essential that the population understands the basics of earthquake hazards and knowledge of how to protect themselves in emergency situations. Schools have been the focus of this education effort. Over 1,140 elementary and middle schools and their neighboring communities and 1.5 million students in Sichuan Province have received disaster risk-reduction education through the “Public Education for Earthquake Hazards” project. On May 12, 2009, the Chinese Government declared May 12 as “Disaster Prevention and Reduction Day”, which is significant in raising awareness in China for the reduction and prevention of future disasters. Since disaster is a fundamental threat to development, the disaster risk-reduction strategies should be integrated into broader development processes. As China recognized in its 2009 White Paper on Disaster Reduction, this needs to occur at both the national and local levels. A long-term national hazards reduction program therefore has been launched following the progress of PWERR, including mapping programs, insurance programs, and prevention and mitigation system programs, to improve integrated disaster prevention and emergency rescue capabilities.

7 Conclusion

Through theoretical research and actual investigation in PWERR, this article has summarized a meta-synthesis pattern of post-disaster recovery and reconstruction, the ideological foundation of which is meta-synthesis methodology, concrete expression is WSR three-dimensional approach, carried out by a PERR integrated framework. Through systematic planning and comprehensive implementation, PWERR has made remarkable achievements in a short time: 95% of the reconstruction work has been finished, and 51 of the most seriously affected counties have been rebuilt over the past 3 years (CNTV 2011). Moreover, significant progress has been made in improving the economic, social and ecological environments, and promoting urban and rural coordinated development, so the local people can enjoy a better life in comparison to the life before the quake hit.

The “Wenchuan Pattern” is a meta-synthesis pattern, which provides a feasible pathway for post-disaster recovery and reconstruction with an integrated solution. Although the devastating Wenchuan earthquake was a catastrophe to Sichuan and China, it was also a trial for the Chinese government and people to comprehensively test their ability to cope with significant natural disasters, successfully rebuild around the altered geography of disaster-stricken areas, and seriously consider the relationship between socioeconomic development and disaster prevention. The lessons of PWERR tell us, post-disaster recovery and reconstruction is a complicated systematic project, the meta-synthesis methodology, WSR three-dimensional approach, and integrated framework are feasible and effective in dealing with this kind of problem.

We all hope that a catastrophe such as the Wenchuan earthquake will not occur again, but Japan's massive Ms9.0 earthquake on Mar 11 2011 is a sobering reminder that disasters continue to threaten human beings around the world. Recently, as global climate change is becoming a threat to humanity, many experts predict this rise in climate-induced extreme weather events will continue in the future (IPCC 2007). Because such disasters are difficult to avoid or prevent, the countries, especially ones prone to disasters, need to establish disaster prevention and response systems. More important is they need to formulate integrated programs for post-disaster recovery and reconstruction, taking the Wenchuan Pattern as a reference.

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