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How Could Community Participation Help to Achieve Build-Back-Better

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ABSTRACT

Seismic events in China cause serious losses in human lives, as well as damage to infrastructure. On May 12th 2008, the Wenchuan Earthquake of magnitude Mw7.9 heavily shocked most of Western China, resulting in large numbers of housing severely damaged or lost. Recovery and reconstruction quickly kicked off in the affected areas, involving local and national governments and other international actors. This paper focuses on community participation in post-earthquake reconstruction projects in rural areas affected by this earthquake, taking the village of Daping in Sichuan province as a case study to discuss how community participation can contribute to 'build-back-better' strategies and sustainable rural development. The reconstruction of Daping took place in 2008 and 2009 after the Wenchuan Earthquake. The authors have explored the process through literature analysis and site investigations, including semi-structured interviews with the local community and local government officials. The local community in Daping drove the building reconstruction, rather than built-environment professionals, and were actively involved in the design and rebuilding process by drawing learnings from traditional building techniques, seismic construction, architectural layout and other vernacular knowledge in relation to dealing with natural changes and the environment. The study exemplifies how community involvement strengthens build-back-better strategies, particularly through the use of local knowledge, which can result in solutions that are better adapted to the needs and the culture of the local communities by enhancing local construction typologies, arranging safer settlements and utilizing more appropriate materials. The findings suggest that regional culture may positively impact post-earthquake reconstruction, supporting the sustainable development of rural areas.

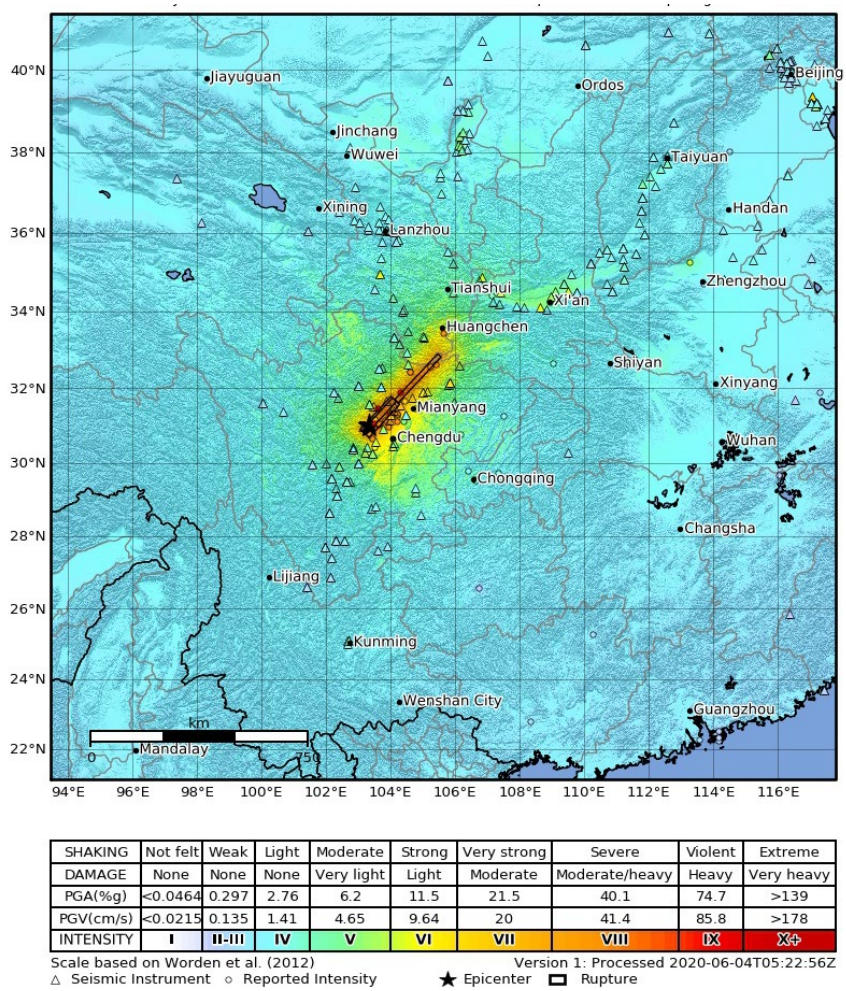
Keywords: post-earthquake reconstruction, community participation, local knowledge, build-back-better

INTRODUCTION

Disaster is the result of both hazards and vulnerabilities (Hewitt, 2011). To mitigate the harm of disasters and minimize undue risk, it is essential to reduce the community's susceptibility to hazards, or 'vulnerability' as defined under the United Nations International Strategy for Disaster Reduction (UNISDR, 2017), and enhance the community's ability to withstand future shocks, or 'resilience' (Kelman, 2017). Post-disaster housing reconstruction can not only reinstate the dwellings lost in a disaster, but also help to stimulate later economic growth in the affected area (Schumacher and Strobl, 2011; Thiruppugazh, 2016). By providing stronger infrastructure and rearranging the production and living order, the post-disaster recovery and reconstruction processes can be an opportunity for laying a solid foundation for local sustainable development (Wisner, Gaillard and Kelman, 2012; Dube, 2020).

This research uses the village of Daping (Sichuan Province, China), reconstructed after the 2008 Wenchuan Earthquake, as a case study. The May 12th 2008 strong earthquake caused 68,858 deaths and hundreds of billions of Chinese Yuan in economic losses, affecting an area of more than 440,000 km^2 (see Fig.1), nearly half of the extent of China (Wang, 2008). Various rescue teams from around the world assisted in the response and recovery. While national reconstruction projects built new counties and towns away from their original locations, many NGOs and volunteers worked in remote countryside areas and guided local villagers to rebuild their houses. Daping Village is selected among those self-built projects using a bottom-up approach for exemplifying the use of vernacular technology in post-disaster reconstruction (PDR).

After the earthquake, NGO Beijing Global Village supported recovery and reconstruction of villages near Wenchuan. They conducted a damage assessment in Daping evidencing that modern brick houses had experienced severe damage, while the local traditional timber frame structures with mortise-tenon joints were still standing albeit slanted (Liu, 2015). To reconstruct the settlement and meet the modern aspirations of local communities, Beijing Global Village organized an expert team of architects, led by Professor Jiaping Liu from Xi'an University of Architecture and Technology (Beijing Global Village, 2009). In 2011, this reconstruction project won the World Habitat Awards for both its ecological design and the economic effect it brought to local villagers (World Habitat Awards, 2012).



SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0464	0.297	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.0215	0.135	1.41	4.65	9.64	20	41.4	85.8	>178
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Worden et al. (2012) Version 1: Processed 2020-06-04T05:22:56Z

△ Seismic Instrument ○ Reported Intensity ★ Epicenter ▭ Rupture

Figure 1. *Macroseismic Intensity Map for Wenchuan Earthquake on 12th May 2008 (United States Global Survey, no date).*

The Daping's reconstruction project is likely to an experimentation in Chinese rural area, which places modern housing functions satisfying the demands of the new era into the traditional building structure, using advanced materials to improve indoor performance. Unlike the residents in neighboring regions who were rehoused to flats in Tongji County and began county life, these villagers in Daping project updated their rural lifestyle on the same land, with the concept of organic environmental protection (Beijing Global Village, 2009). In the past, villagers made their living by planting and collecting herbs. After the reconstruction, by following natural climates and using biological fertilizer, the community established an organic farming system. Animal husbandry is performed in an eco-friendly way by selecting non-transgenic strains, wild breeding, crop feeding and manual handling. This is more expensive than other strategies, but the combination of organic farming and herb cultivation promotes the protection of local ecosystems, and this has resulted in Daping becoming a destination for ecotourism. During hot summertime, urban residents from Chengdu and other cities arrive in Daping and stay in the reconstructed traditional houses with better thermal performance, taste organic foods, hike in the mountains and enjoy the extensive natural landscape.

LITERATURE REVIEW

Post-Disaster Reconstruction and Build-Back-Better

Facing the broken, damaged or even collapsed housing condition, the household resettlement and housing reconstruction in the disaster-afflicted areas are essential during the post-disaster recovery process (Ahmed and Charlesworth, 2014; Gunawardena *et al.*, 2014; Mohtat and Zargar, 2018). In the last two decades, the concept of build-back-better (BBB) has emerged as a guiding principle of post-disaster recovery and reconstruction efforts. It was coined after the 2004 Indian Ocean Earthquake and Tsunami (Kennedy *et al.*, 2008) to require the recovery condition in affected areas not to be reinstated back to pre-disaster standards, but to enhance resilience against future hazards (Mannakkara and Wilkinson, 2015). The 2015 Sendai Framework established BBB as one of the key principles of post-disaster recovery, rehabilitation and reconstruction in order to reduce future disaster risk by 'enhancing disaster preparedness for effective response' (UNISDR, 2015). However, the meaning of 'better' in relation to housing reconstruction remains under-explored, leaving architects and researchers with ambiguous information and lacking reliable standards (Maly, 2018). This paper looks at Daping reconstruction project through the lens of BBB to identify those principles of the reconstruction initiative that contributed to BBB, with a focus on the participation of the local community and their culture.

The focus in this study is placed on housing reconstruction as an essential element of post-disaster recovery. Besides providing the shelter for the community, the reconstruction also solves the problems in old houses to adapt to modern life during the building process, such as energy conservation and pollution reduction.

Top-down and Bottom-up Pattern

According to the United Nations Disaster Assessment Coordination (UNDAC) Field Handbook, the 'disaster-affected country bears the primary responsibility for human assistance and coordination' (UN, 2018). The significance of other organisations, such as NGOs and IGOS, has also been gradually recognized to offer an effective international emergency response (Deng, 1998). Early studies showed that when external resources and assistance were insufficient, the speed and quality of the recovery depended heavily on the organizational and leadership skills of the community, which had a dominant effect on the recovery (Rubin, Saperstein and Barbee, 1985). The speed of external post-disaster aid can vary significantly. Access to disaster sites is a key factor, for example, remote rural regions with low economic development sometimes experience delayed financial and technical assistance (Albuerne et al, 2021). Besides, government-led reconstruction of damaged areas can sometimes fail for not being able to meet the actual demands of local residents (Gao, 2012). In situations when the outside help is little, humanitarian actors look at self-recovery which encourages disaster-affected communities to repair or rebuild their shelters (Twigg *et al.*, 2017). The interdisciplinary collaboration between professionals and non-professionals can benefit post-disaster interventions and effectively support locals to self-build their houses with specialized guidance.

In China, the disaster risk reduction experiences two time periods. Chinese government used concentrated disaster-response mechanisms since 1949, and the project of PDR heavily depended on military and government departments (Daly, 2016). In 1980, the government approved the Consultation on Acceptance of Aid from the United Nations Disaster Relief Office (UNDRO) which welcomed the outside assistance with rescue and reconstruction in later disasters, and the 2008 Wenchuan Earthquake of magnitude Mw7.9 was the prime example (Kang, 2015). The strong earthquake shook more than half of China and this disaster became the most destructive and widespread earthquake since the foundation of the country in 1949. After that, a large number of non-governmental organizations (NGOs) and other social organizations went to Wenchuan and broadly participated in the post-disaster rescue and recovery process, which was the first sign of the bottom-up approach for disaster relieve in the nation (Hui, 2009; Shieh and Deng, 2011). The records published by the State Council showed that during the rescue and recovery process after the Wenchuan Earthquake, there were about three million foreign and domestic volunteers taking part in the rescue operations, and over 300 NGOs and volunteer groups were active in the affected areas (Zhu and Hu, 2011). The effective participation of civic groups made up the insufficiency of the government and market regulation and played a highly significant part in the follow-up rural reconstruction projects (Zou, 2009; Gao, 2012). Since then, the civilian force received the official attention.

Vernacular Buildings and Local Knowledge

According to the 1999 ICOMOS Charter, the vernacular building is 'the traditional and natural way by which communities house themselves' (ICOMOS, 1999). However, the expansion of the urban area and the erosion of traditional building techniques and knowledge due to fast-speed modernization threatened rural traditional housing (Porto, Leanza and Cascone, 2012). Vernacular architecture often receives low regulation standards and protections, which further threatens its continuation (Zhu, 2018). There were 5709 traditional villages left in China in 2010, having 41.2% lost compared to the total amount of 9707 in 2004 from the data collected by Chinese authorities (Hu, 2017). In recent decades, people started to look back and learn from vernacular architecture, appreciating its sustainability in three aspects: environmental, economic and cultural (Kazimee, 2008; Alves, 2017; Salman, 2018; Liu *et al.*, 2019). Environmental sustainability is manifested in its constructing technologies and techniques, including the lower carbon footprint, less energy consumed compared to modern architecture and a more comfortable indoor architectural performance. Economic sustainability is realized in the efficient management of local materials and regional resources, and cultural sustainability is exhibited in its preservation of cultural landscape, the establishment of collective memories and local identities, inspiration on human creativities and its inheritance of the tangible architectural forms as well as the intangible traditional crafts and techniques (Gamón, 2020; Olukoya and Atanda, 2020). The vernacular dwellings in Sichuan Province are discussed in section 3, where their sustainable attributes are discussed.

As early as the 1970s, scholars discussed the role local knowledge played in the development and conservation of the environment, but the indigenous culture was still widely understood as 'non-knowledge', 'primitive' and an obstacle to the development (Dekens, 2007). The involvement of local knowledge in post-disaster development has been more broadly recognized since the 2004 Indian Ocean Earthquake and Tsunami, when people found that local knowledge could assist in disaster risk management (Arshad and Athar, 2013; Podder *et al.*, 2014). UNESCO identified the contribution of local knowledge in the disaster preparedness, post-disaster response and recovery process (UNESCO, 2017). Better comprehension of local knowledge could facilitate its application to disaster-related challenges, with the help of modern science and technologies (Williams and Hardison, 2013). Moreover, recognizing the positive effects of local knowledge in disaster context foster the public awareness of values of intangible cultural heritage (ICH), which benefits the safeguarding of ICH (UNESCO, 2017).

Before the 2008 Wenchuan Earthquake, residential buildings in remote areas of Sichuan Province primarily comprised of brick and concrete, replacing the traditional timber-framed structures, under the impact of industrialization and modernization since the 1980s (Li, 2016). However, after the earthquake, some timber-framed traditional architecture exhibited their great seismic-resistant capacity, and were modeled by local communities during the reconstruction process for its low-cost and stable structure (Liu, 2015). The materials of traditional architecture came from locally-sourced timbers, and local communities retrieved the building techniques from local knowledge and carpenters. This paper regards local knowledge as a primitive tool of the reconstruction and explores how it has been applied during this process and its effect on the outcome.

METHODOLOGY

This paper analyses the reconstruction process carried out in in the village of Daping after the Wenchuan Earthquake. It does so through the review of documentary sources and primary data collected in a fieldwork campaign in January 2020.

The reconstruction project handbook and documentary photos are obtained from the management council of Daping Village, run jointly by the village committee and Beijing Global Village. Other documentation and data are provided by Prof Jiaping Liu's team at Xi'an University of Architecture and Technology, containing the building design concept for reconstructed housing and experimental data comparing indoor environments in surviving old buildings and reconstructed buildings, collected in July 2009 and February 2010.

Fieldwork comprises transect walks through Daping to observe and document pre- and post-earthquake construction and semi-structured interviews with locals and visitors. Eight participants are interviewed, including three local residents, three village administrators and two tourists (Table 1). Different interview questions are used for different groups (Table 2). Interviews were conducted in Chinese (Mandarin) and Sichuan dialects, recorded through hand-written notes.

Table 1. *Information of Interview Participants*

	Group	Origin	Occupation
P1	Local residents	Daping Village	Farmer, an owner of a homestay
P2	Local residents	Daping Village	Farmer, an owner of a homestay
P3	Local residents	Daping Village	Farmer
P4	Village administrators	Daping Village	The secretary of Daping Village
P5	Village administrators	Daping Village	The director of the management committee
P6	Village administrators	Daping Village	A member of the community service station
P7	Tourists	Other	Self-employed entrepreneur
P8	Tourists	Other	Student

Table 2. *Interview Questions*

	Questions for local residents	Questions for administrators	Questions for tourists
1	What did your original house look like? What was it made of?	What was the cooperation with the expert team like during the reconstruction?	How well do you know the village?
2	What was the impact of the Wenchuan Earthquake on your house?	Did villagers contribute any ideas to the expert team during the design phase of the reconstruction?	What is your first impression of the village ?
3	What was the cooperation with the expert team like during the reconstruction?	In your opinion, what do villagers think of their houses after rebuilding?	Could you describe any characters of the buildings in Daping Village?
4	Do you think the newly built house preserves the traditional taste?	Have you felt any seismic events after this reconstruction? Is there any impact on the housing?	Have you experienced any seismic events during your stay? Is your living place strong enough?
5	How would you compare the new house with the original one?	Do newly built houses bring any new opportunities to the village?	
6	Have any problems arisen with the new reconstructed housing?		
7	How do you feel about the seismic-safety of the newly built house?		

RESULTS

Daping Village is located in the western part of Tongji County, 65 kilometers northwest to Chengdu City, the capital of Sichuan Province (see Fig.2). During the 2008 Wenchuan Earthquake, Tongji County, on the Longshan seismic belt, was one of the most affected regions, causing 76,597 houses collapsed and 2,271 houses damaged in total (Li, 2016). The modern dwellings in Daping Village were built of one-brick thick walls for saving the construction costs, which during the earthquake proved to be too thin to resist strong seismic shaking (Liu, 2015). The traditional vernacular buildings in *Chuandou* style (Liu, 2008), also known as column-and-tie frame, were comparatively more resistant to seismic activity with only the lightweight envelope failing while the skeleton survived (Beijing Global Village, 2009), as in Fig.3.

Daping Village comprises 283 families and over 200 residential buildings, with some households with multiple generations of a family (Liu, 2015). According to P4's narration, during the post-earthquake reconstruction, some villagers chose to move to the prefabricated houses near Tongji County allocated by Chengdu municipal government, while 44 families were willing to rebuild their houses in the original locations, convenient for

growing their crops nearby. To improve transport links, thanks to charitable funds residents built a 3m. wide modern road to replace the old track that was less than 1m. wide. For the reconstruction of their housing, residents collaborated with Beijing Global Village and Prof Jiaping Liu's expert team and participated in the overall process including plan selection, building construction (which helped reduce costs), technical assistance and daily maintenance.

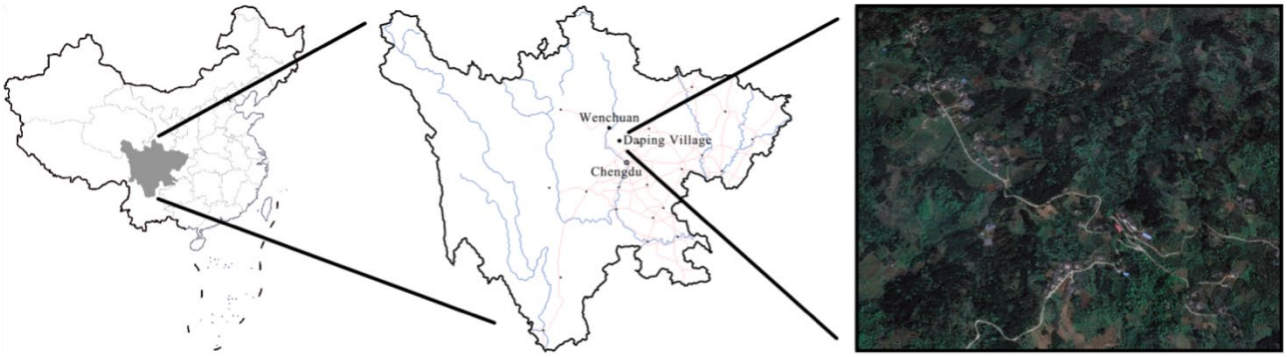


***Figure 2**. Location of Daping Village, with maps from ChinaMaps.org, d-maps.com and Google Earth*

***Figure 3**. A Traditional Building in Daping Village Survived through the Wenchuan Earthquake*

According to P1's narration, at the beginning of the collaboration local communities expressed their aspiration that the reconstructed village would help them in 'keeping up with modern society for at least thirty years'. To save costs in the reconstruction, villagers opted to use materials from collapsed buildings and timbers from their private land. Considering that the major hazard in Daping Village is still the earthquake, the architects proposed the use of *Chuandou* frame construction as the local traditional seismic-resistant structure to deal with the hazard vulnerability (Liu, 2015). During the reconstruction, the architects discussed the individual household requirements for their new houses, and every new building design proposal was reviewed and approved by the village committee (Cheng *et al.*, 2011). Signatures and fingerprints of the house owners were collected to show consent to the reconstruction plan. Fig.4 shows a villager expressing his ideas about the design proposal during the public assessment process. At the construction stage, young and middle-aged adults in each household worked together to lay the foundations, erect the timber frame and build the exterior walls. Over 200 families were reconstructed following this consultative process and applying this construction system inspired by vernacular architecture and supplied by local materials (Liu, 2015).

There is no universal standard for evaluating PDR, and scholars measure the performance of reconstruction in several aspects. After the 2004 Indian Ocean tsunami, scholars evaluated the reconstruction by taking housing quality, community infrastructure, risk reduction and livelihood as four indicators (Jordan, Javernick-Will and Amadei, 2015). Su (2019) used Matlab analytic hierarchy process and expanded the housing quality into site selection, structure style, fire prevention system and building energy efficiency. Tumini enlarged the context of reconstruction into the city level and used urban morphology analysis framework as the resilience indicators, including 'population density (PD)', 'relationship between unbuilt and built areas (BI)' and 'useful temporary

secure open spaces (SOSs)' (Tumini, Villagra-Islas and Herrmann-Lunecke, 2017). The community feedback after the reconstruction also serves as a significant indicator (Rahmayati, 2016). PDR not only aims at providing shelter needs for disaster-affected communities but contributes to the long-term recovery. Thus, besides the physical and morphological indicators, scholars (Chen and Tang, 2018) took economic indicators to measure the time spent in restoring to the pre-disaster level as a standard of evaluating the recovery. Twigg explored an interdisciplinary research to evaluate the self-recovery projects in Nepal and Philippines, using building appraisal and focus group or community discussion to evaluate the reconstruction and applying Timeline Mapping method during interviews and discussions to understand the long-term recovery plans of local community (Twigg *et al.*, 2017).

Figure 4*. The Public Assessment of the Reconstructed Design Draft (source: Daping Village Committee 2009).*

As a case in a village, the promoting effect of Daping PDR project to local economic and social development is hard to measure. Therefore, the resilience indicators are defined as 'labor cost', 'seismic resistance', 'energy consumption reduction' and 'cultural identity'. Considering the reconstructed Daping Village becomes a destination for eco-tourism and the rebuilt dwellings are utilized as homestays during the holiday, measuring the time and effort spent in building reconstruction could be an evaluation criterion, as like the labor cost, which proves the convenience and duplication of the reconstructed housing. The seismic performance, as an essential criterion for discussing the resilience of a post-disaster community, evaluates the architectural quality to resist future seismic activities. As a low-cost structure applying local knowledge during the construction, the evaluation standards also come from environmental and cultural aspects, which indicate the resilience in environmental sustainability and local identity. The resilience indicators, evaluation criteria, supporting evidence, contributions of local community and application of local knowledge are presented in Table 3 and further discussed in following paragraphs.

Table 3. *The Project Evaluation for Daping Village Reconstruction*

Resilience indicators	**Evaluation criteria**	**Supporting evidence**	**Contributions of local community**	**Application of local knowledge**
Labor cost	Rapid completion	Using local materials Having local workforce Ease of installation structure	Providing local materials Using self-build mode	Simplicity of the *Chuandou* style

Seismic resistance	Improved seismic performance	Using the *Chuandou* style framework Tiling the roof directly on the roof trusses	Providing skilled carpenters and builders	Seismic resistance of the *Chuandou* style Local building techniques
Energy consumption reduction	Advanced environmental performance	Natural ventilation and lighting Using low carbon materials Using renewable energy	Providing local materials and building skills	Architectural layout traditions Building skills responding to local climate
Cultural identity	Reviving cultural tradition	Following traditional building styles Considering both traditional and modern lifestyles Promoting local economic growth and eco-tourism development	Daily maintenance	Traditional building style Architectural layout traditions

Labor Cost

The ancient *Chuandou* architectural style is characterized by a timber frame structural system in which columns are connected through mortise and tenon joints with a series of beams forming a truss (see Fig.5) and uses purlins at the upper ends of columns to connect adjacent trusses (Zwerger, 2012), as in Fig.6. The space between every two trusses is termed as a *Jian*, which is a basic inner building unit in Chinese traditional architecture. By erecting more trusses, a larger interior space and a more flexible spatial organization could be easily constructed (see Fig.6).

Figure 5*. The Truss Made up of Columns and Beams (source: Daping Village Committee 2009).*

Seismic Resistance

The mortise and tenon joints connecting beams to columns and columns to purlins in the *Chuandou* style guarantee the interlocking within these parallelogram frames, forming a flexible structure that could dissipate a portion of the seismic energy through structural distortion, reducing the risk of overall failure of the building. This behavior was observed in Daping after the 2008 Wenchuan earthquake. However, using timber as the material has potential risks of getting damp or seasonal cracks. To avoid this problem, villagers used timbers cut down in spring because the moisture content of timbers at that time could stabilize at between 8% to 13%

which is close to the standard moisture content of timbers in Chengdu's climate (Docsou, 2013), making the timbers more resistant to the dry or moist environment (Dong and Liu, 2014; Loffer, 2020). If the reconstruction money is well-funded, such as for some public buildings (see Fig.7), builders could use light steel to replace the timber and build the frames, but the skeleton is supposed to keep the *Chuandou* style to resist earth-quake forces. For safety during earthquakes, roof tiles are nailed on the rafters to attenuate the seismic force, rather than received with mortar (Huang, 2013).

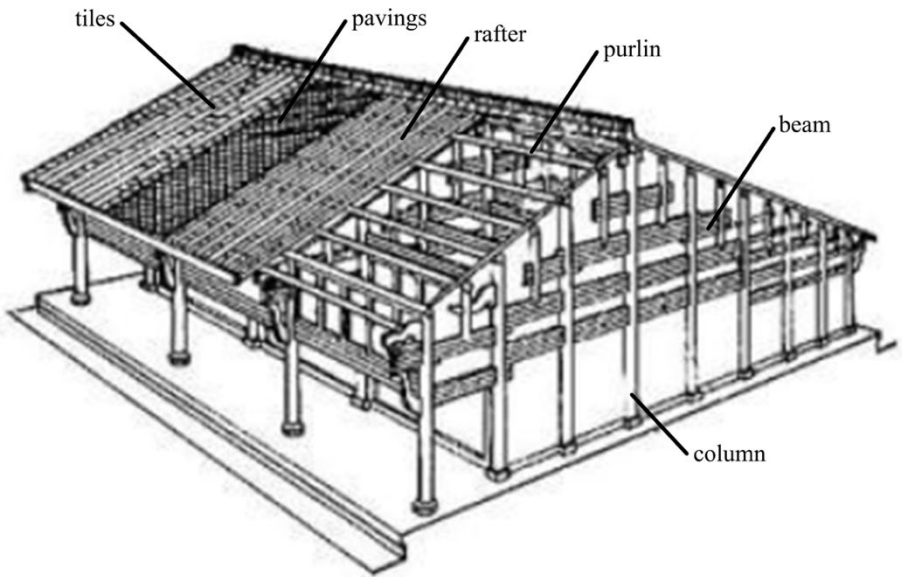


***Figure 6**. The Chuandou Architectural Style (Liu, 2008).*

***Figure 7**. The Internal and External Pictures of the Reconstructed Community Hall.*

Energy Consumption Reduction

In traditional *Chuandou* construction, there is typically a lightweight building envelope made of timbers or woven mats. However, these walls are too thin to provide sufficient thermal insulation in winter or suitable sound insulation. Meanwhile, the eaves around the inner courtyard and above the outdoor corridors, which can be over two-meter width, to reduce the glare and keep rainfall away from the timber structure, protecting it from water-induced damage. At the same time, the long eaves impact interior lighting in the centre of the building, a situation that is worsened in Daping because traditional buildings in the village do not have windows on the back elevation.

To meet the residents' modern habitability expectations, the architect team improved the building performance while aiming to respect the architectural traditions. They designed cavity walls made of bamboo and timbers on the outer layers, with an internal fill layer made either of earth or Expanded Polystyrene (EPS) foam

insulation boards with damp-proof course (Gao *et al.*, 2014). The new reconstructions ensure natural ventilation and lighting by reducing the width and depth of building units and enlarging the windows.

With the assistance of experts, villagers constructed methane tanks utilizing straw from local coptis plants and excrement of livestock as fuel, providing clean energy for a portion of the daily heating and cooking, instead of cutting down forests as in the past.

Cultural Identity

The reconstruction follows the cultural tradition of western Sichuan's vernacular houses. Before the Qin Dynasty unified China in 221BC, Sichuan was inhabited by minorities. Soft marshland was predominant in the area. To disperse moisture and ventilate the room, ancient Sichuan people built timber stilt-houses, raised above the ground in response to the local climate (Zhang, 2013; Li, 2016). After Qin conquered Sichuan, the rivers and watercourses underwent careful management, greatly improving the damp environment. With the arrival of Qin's people, the architecture style of Sichuan vernacular dwellings also changed, becoming more alike the post and lintel construction known as *Tailiang* style (Dong, 2010), which is a typical structure in northern China using posts and lintels to load. As in Fig.8, lintels load the purlins or through upper posts, and then distribute the load through bottom posts to columns.

Since the Qing Dynasty (1644-1912), frequent wars heavily reduced the population in Sichuan, and immigrants from the southeastern part of China came to Sichuan to settle down. At that time, *Chuandou* style replaced *Tailiang*, becoming the main current architecture form of Sichuan vernacular architecture until today. Compared to *Tailiang*, *Chuandou* style uses less timber and has better seismic capacity (Sun *et al.*, 2019), but the indoor space is interrupted by columns required to support the roof. When the enthusiastic waves of modernism make people see the traditional architecture as outdated, people in rural areas prefer to tear down old wooden houses and rebuild new ones made of bricks and concrete (Zhao, 2016). However, dilapidation of brick houses and survival of traditional houses consolidated the values of the latter (Beijing Global Village, 2009), which was also learnt from P2 and P6's narration.

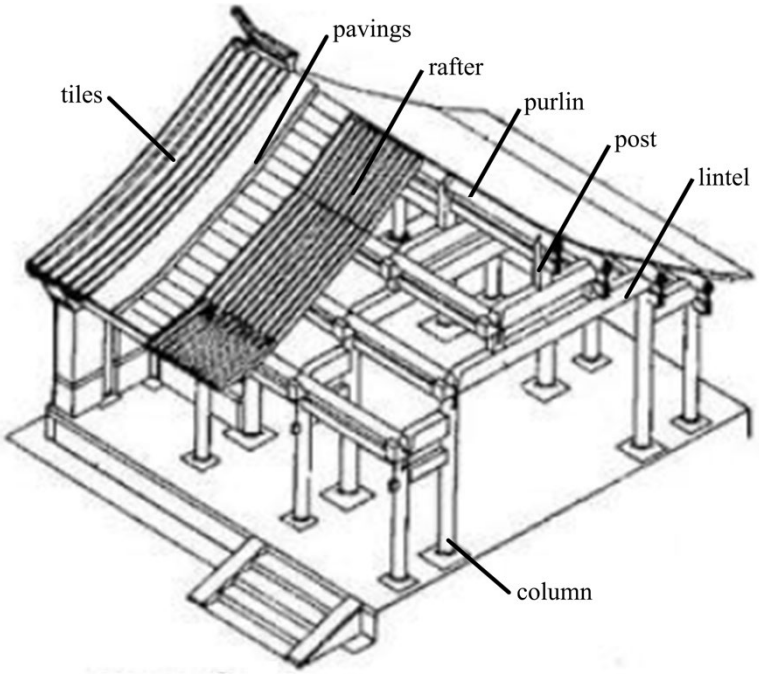


Figure 8. *The Tailiang Architectural Style (Liu, 2008).*

With larger indoor space, the reconstructed buildings could serve multiple modern functions. The new houses were arranged in L-shape or U-shape, with a central hall and master bedrooms in the north-south orientation, multi-purpose rooms in the east-west direction and kitchen, bathroom or storage at the corner, as in Fig.9. The multi-purpose rooms could be used as secondary bedrooms, activity rooms, or dining halls depending on the personal preference of house owners.

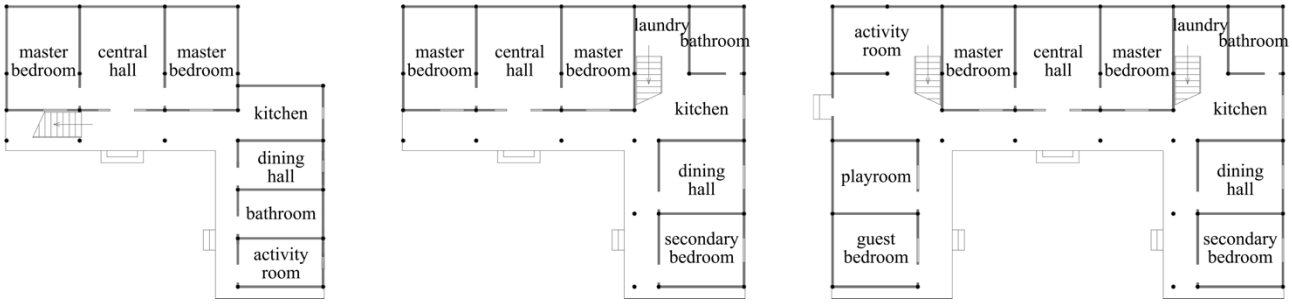


Figure 9. *The Different Spatial Organization of Reconstructed Dwellings (Liu, 2015).*

CONCLUSIONS

This research uses the village of Daping as a case study to discuss the role local community could play in achieving BBB in PDR projects. In the aftermath of the 2008 Wenchuan earthquake, the villagers in Daping initiated, as both the drivers and beneficiaries, the self-build reconstruction of their dwellings on the original location, replicating the traditional timber structures under the guidance and supervision of experts from Xian University.

The project could be characterized by four performance criteria:

- Rapid completion: in the given context of inadequate road access, lack or shortage of building materials and urgent demand for housing reconstruction, the use of the traditional building style and local materials helps the community quickly rebuild their living environment.
- Improved seismic performance: the stability of traditional building forms has been tested by the disaster, so its reuse in the reconstruction supports safe performance.
- Environmental performance: the improvements in indoor luminous and thermal environment, application of low carbon materials and renewable energy as well as the construction of methane tanks meet the modern demands of the local community and set up a harmonious co-existence between humans and nature.
- Reviving the cultural tradition: the successful incorporation of modern construction and renovation principles into vernacular architecture assert the values of the traditional buildings and the traditional building techniques, which both rebuild the confidence of local people and enhance the local cultural identity.

Therefore, the ‘better’ in build-back-better strategy in this case could be understood as faster and safer support and construction, as more environmentally-friendly lifestyle and prouder people.

The active involvement of local communities helps to preserve vernacular heritage by exploring their values in modern society and also contributes to local sustainable development by restructuring living conditions. After a disaster, communities have the opportunity to reconsider the value of their traditional buildings and local knowledge, reevaluating vernacular architecture with consideration to its application today.

REFERENCES

Ahmed, I. and Charlesworth, E. (2014) ‘Post-Disaster Housing Reconstruction to Enable Resilient Communities’, *Open House International*, 39(3), pp. 4–6.

Alves, S. (2017) ‘The Sustainable Heritage of Vernacular Architecture: The Historic Center of Oporto’, *Procedia environmental sciences*, 38, pp. 187–195. doi:10.1016/j.proenv.2017.03.105.

Arshad, S. and Athar, S. (2013) *Rural housing reconstruction program post-2005 earthquake : learning from the Pakistan experience : a manual for post-disaster housing program managers*. 77907. The World Bank, pp. 1–116. Available at: http://documents.worldbank.org/curated/en/488031468286831605/Rural-housing-reconstruction-program-post-2005-earthquake-learning-from-the-Pakistan-experience-a-manual-for-post-disaster-housing-program-managers (Accessed: 19 February 2020).

Beijing Global Village (2009) *Eye of the Farmers: Our Community*. CRCF LOHAS.

Chen, S. and Tang, Y. (2018) 'Performance Measurement of Post Disaster Reconstruction: Taking Wenchuan, Yushu, Lushan Earthquake as Examples', *Journal of Chongqing University (Social Science Edition)*, 24(6), pp. 22–32.

Cheng, H. *et al.* (2011) 'Eco-Friendly Vernacular Rural Housing in Western China: a Case Study of a Reconstruction Project after 2008 Sichuan Earthquake', *Applied Mechanics and Materials; Zurich*, 99–100. doi:http://dx.doi.org.ezproxy.cul.columbia.edu/10.4028/www.scientific.net/AMM.99-100.638.

Daly, P. (2016) 'Cycles of Destruction and Reconstruction: Responding to Disasters in Asia', in Daly, P. and Feener, R.M. (eds) *Rebuilding Asia Following Natural Disasters: Approaches to Reconstruction in the Asia-Pacific Region*. Cambridge: Cambridge University Press, pp. 1–56. doi:10.1017/CBO9781139683548.002.

Dekens, J. (2007) *Local Knowledge for Disaster Preparedness: A literature Review*. International Centre for Integrated Mountain Development (ICIMOD). Available at: https://agris.fao.org/agris-search/search.do?recordID=QZ2013000064 (Accessed: 7 January 2021).

Deng T. (1998) *The Relieving History of China*. Beijing Publishing House.

Docsou (2013) *The Annual Average Equilibrium Moisture Content (EMC) of Wood in China*. Available at: https://doc.docsou.com/b80c78f3b32c8b746eedb0775.html (Accessed: 2 June 2021).

Dong, W. (2010) *The Researches on Constitution of Form and Environment Composition in Domestic houses of Western Sichuan*. Master. Central South University of Forestry and Technology. Available at: https://kns.cnki.net/kcms/detail/detail.aspx?dbcode=CMFD&dbname=CMFD2012&filename=1011063040.nh&v=Gnj7RIjo9JHDtdfCPZ%25mmd2BTctViP%25mmd2BuBBCxhP15nFJIc7NqEIJX5nIG6FCm37lzzriXY (Accessed: 25 February 2021).

Dong W. and Liu G. (2014) *The Culture of Water and Water Engineering*. Beijing Book Co. Inc.

Dube, E. (2020) 'The build-back-better concept as a disaster risk reduction strategy for positive reconstruction and sustainable development in Zimbabwe: A literature study', *International Journal of Disaster Risk Reduction*, 43. doi:10.1016/j.ijdrr.2019.101401.

Gamón, M.R. (2020) 'PARAMETERS OF SOCIOCULTURAL SUSTAINABILITY IN VERNACULAR ARCHITECTURE', *International archives of the photogrammetry, remote sensing and spatial information sciences.*, XLIV-M-1–2020, pp. 227–231. doi:10.5194/isprs-archives-XLIV-M-1-2020-227-2020.

Gao, J. (2012) *Rural Housing Construction Paradigm and Strategy Research Based on Wenchuan Earthquake Reconstruction and Settlement*. Doctoral. Zhejiang University. Available at: http://kns.cnki.net/KCMS/detail/detail.aspx?dbcode=CDFD&dbname=CDFD1214&filename=1013147753.nh&v=Mjg4MDhHZGJKckpFYlBJUjhlWDFMdXhZUzdEaDFUM3FUcldNMUZyQ1VSTE9mWU9kbkZpM2tXNy9CVkYyNkhiSzg= (Accessed: 18 July 2019).

Gao, Y. *et al.* (2014) 'Research on the Design of Ecological Regeneration of Rural Newly-Built Residences in Mountain Region of Pengzhou City, Sichuan Province', *Journal of Xi'an University of Technology*, 30(01), pp. 52–57.

Gunawardena, T. *et al.* (2014) 'Time-Efficient Post-Disaster Housing Reconstruction with Prefabricated Modular Structures', *Open House International; Gateshead*, 39(3), pp. 59–69.

Hewitt, K. (2011) 'Culture, Hazard and Disaster', in *The Routledge Handbook of Hazards and Disaster Risk Reduction*.

Hu B. (2017) *Investigation Report on the Protection of Chinese Traditional Villages (2017)*. Social Sciences Academic Press(CHINA).

Huang, Q. (2013) 'Construction Technology of Positive Sloping Roof-Mounted Waterproof Tile hanging Complete System', *Guangdong Architecture Civil Engineering*, 20(12), pp. 30-33+16.

Hui, D.L.H. (2009) 'Politics of Sichuan Earthquake, 2008', *Journal of Contingencies and Crisis Management*, 17(2), pp. 137–140. doi:https://doi.org/10.1111/j.1468-5973.2009.00571.x.

ICOMOS (1999) 'Charter on the Built Vernacular Heritage', *Global Heritage Fund*. Available at: https://globalheritagefund.org/ghf_resources/charter-on-the-built-vernacular-heritage/ (Accessed: 18 July 2019).

Jordan, E., Javernick-Will, A. and Amadei, B. (2015) 'Post-disaster reconstruction: lessons from Nagapattinam district, India', *Development in practice*, 25(4), pp. 518–534. doi:10.1080/09614524.2015.1028334.

Kang, Y. (2015) *Disaster Management in China in a Changing Era*. Berlin Heidelberg: Springer-Verlag (SpringerBriefs in Political Science). doi:10.1007/978-3-662-44516-7.

Kazimee, B.A. (2008) 'Learning From Vernacular Architecture: Sustainability And Cultural Conformity', *WIT Transactions on Ecology and the Environment*, 113, pp. 3-. doi:10.2495/ARC080011.

Kelman, I. (2017) 'Linking disaster risk reduction, climate change, and the sustainable development goals', *Disaster prevention and management*, 26(3), pp. 254–258. doi:10.1108/dpm-02-2017-0043.

Kennedy, J. *et al.* (2008) 'The Meaning of "Build Back Better": Evidence From Post-Tsunami Aceh and Sri Lanka', *Journal of contingencies and crisis management*, 16(1), pp. 24–36. doi:10.1111/j.1468-5973.2008.00529.x.

Li, C. (2016) *Western Sichuan Timberwork Residence Investigation and Building Construction*. Master. Xi'an University of Architecture and Technology. Available at: https://kns.cnki.net/kcms/detail/detail.aspx?dbcode=CMFD&dbname=CMFD201701&filename=1016740661.nh&v=mOE336AqiG51Ukc2GD5LI2FCHut45UC0BAIsvMu01uOfhdWbGjhaGAteRmj83ONP (Accessed: 25 February 2021).

Liu, D. (2008) *History of Chinese Ancient Architecture*. China Architecture & Building Press. Available at: https://book.douban.com/subject/1124895/ (Accessed: 13 May 2021).

Liu, J. (2015) *The Practice of Green Building in Western China*. 1st edition. Beijing: China Architecture & Building Press.

Liu, Q. *et al.* (2019) 'Cultural Sustainability and Vitality of Chinese Vernacular Architecture: A Pedigree for the Spatial Art of Traditional Villages in Jiangnan Region', *Sustainability (Basel, Switzerland)*, 11(24), pp. 6898-. doi:10.3390/su11246898.

Loffer, L. (2020) *What Are Acceptable Moisture Levels in Wood?*, *Wagner Meters*. Available at: https://www.wagnermeters.com/moisture-meters/wood-info/acceptable-moisture-levels-wood/ (Accessed: 2 June 2021).

Maly, E. (2018) 'Building back better with people centered housing recovery', *International Journal of Disaster Risk Reduction*, 29, pp. 84–93. doi:10.1016/j.ijdrr.2017.09.005.

Mannakkara, S. and Wilkinson, S.J. (2015) 'Supporting post-disaster social recovery to build back better', *International Journal of Disaster Resilience in the Built Environment*, 6(2), pp. 126–139. doi:10.1108/IJDRBE-06-2013-0019.

Mohtat, N. and Zargar, A.H.I. (2018) 'Sustainability evaluation of post-disaster housing reconstruction after 55 years: Rudak village, Iran', *International Journal of Disaster Resilience in the Built Environment*, 9(4/5), pp. 294–316. doi:10.1108/IJDRBE-08-2017-0050.

Olukoya, O.A.P. and Atanda, J.O. (2020) 'Assessing the Social Sustainability Indicators in Vernacular Architecture—Application of a Green Building Assessment Approach', *Environments (Basel, Switzerland)*, 7(9), pp. 67-. doi:10.3390/environments7090067.

Podder, R. *et al.* (2014) *From Local Building Practices to Vulnerability Reduction: Building Resilience through Existing Resources, Knowledge and Know-how*, *Procedia Economics and Finance*. doi:10.1016/S2212-5671(14)01020-X.

Porto, S.M.C., Leanza, P.M. and Cascone, G. (2012) 'Developing Interpretation Plans to Promote Traditional Rural Buildings as Built Heritage Attractions: Promoting Traditional Rural Buildings', *International Journal of Tourism Research*, 14(5), pp. 421–436. doi:10.1002/jtr.869.

Rahmayati, Y. (2016) 'Reframing "building back better" for post-disaster housing design: a community perspective', *International Journal of Disaster Resilience in the Built Environment*, 7(4), pp. 344–360. doi:10.1108/IJDRBE-05-2015-0029.

Rubin, C.B., Saperstein, M.D. and Barbee, D.G. (1985) *Community recovery from a major natural disaster*.

Salman, M. (2018) 'Sustainability and Vernacular Architecture: Rethinking What Identity Is', *Urban and Architectural Heritage Conservation within Sustainability* [Preprint]. doi:10.5772/intechopen.82025.

Schumacher, I. and Strobl, E. (2011) 'Economic development and losses due to natural disasters: The role of hazard exposure', *Ecological Economics*, 72, pp. 97–105. doi:10.1016/j.ecolecon.2011.09.002.

Shieh, S. and Deng, G. (2011) 'An emerging civil society: The impact of the 2008 Sichuan earthquake on grass-roots associations in China', *The China Journal*, 2011, pp. 181–194. doi:10.2307/25790563.

Su, H. (2019) 'Quality Evaluation of Post-earthquake Recovery and Reconstruction Projects Based on Matlab AHP', *China Earthquake Engineering Journal*, 41(3), pp. 793–799.

Sun, J. *et al.* (2019) 'Experimental Investigation and Mechanical Bebaviour of Post-and-Lintel Timber Frame and Column-and-Tie Timber Frame in Ancient Timber Structures', *Journal of Building Structures*, 40(07), pp. 79–88.

Thiruppugazh, V. (2016) 'Positioning stakeholders within Owner-driven post-disaster reconstruction approaches: Gujarat, India following the 2001 earthquake'. Cambridge University Press.

Tumini, I., Villagra-Islas, P. and Herrmann-Lunecke, G. (2017) 'Evaluating reconstruction effects on urban resilience: a comparison between two Chilean tsunami-prone cities', *Natural Hazards*, 85(3), pp. 1363–1392. doi:10.1007/s11069-016-2630-4.

Twigg, J. *et al.* (2017) *Self-recovery from disasters: an interdisciplinary perspective*. doi:10.13140/RG.2.2.25943.78242.

UN (2018) ‘United Nations Disaster Assessment Coordination (UNDAC) Field Handbook 7th version 2018’. Office for the Coordination of Humanitarian Affairs. Available at: https://www.eecentre.org/resources/undac-field-handbook-7th-version-2018/ (Accessed: 20 July 2019).

UNESCO (2017) *Safeguarding and Mobilising Intangible Cultural Heritage in the Context of Natural and Human-induced Hazards*. Available at: /paper/Safeguarding-and-Mobilising-Intangible-Cultural-in/653e6798c73f91732de0c19a2bb21ee56d5638d7 (Accessed: 24 May 2021).

UNISDR (2015) ‘Sendai Framework for Disaster Risk Reduction 2015 - 2030’, *UNISDR (United Nations International Strategy for Disaster Reduction)*, p. 37.

UNISDR (2017) ‘UNISDR Annual Report 2017’. Available at: https://www.undrr.org/publication/unisdr-annual-report-2017 (Accessed: 6 January 2021).

United States Global Survey (no date) *M 7.9 - eastern Sichuan, China*. Available at: https://earthquake.usgs.gov/earthquakes/eventpage/usp000g650/region-info (Accessed: 13 April 2021).

Wang, Z. (2008) ‘A preliminary report on the Great Wenchuan Earthquake’, *Earthquake Engineering and Engineering Vibration*, 7(2), pp. 225–234. doi:10.1007/s11803-008-0856-1.

Williams, T. and Hardison, P. (2013) ‘Culture, law, risk and governance: contexts of traditional knowledge in climate change adaptation’, *Climatic Change*, 120(3), pp. 531–544. doi:10.1007/s10584-013-0850-0.

Wisner, B., Gaillard, J.C. and Kelman, I. (2012) *The Routledge handbook of hazards and disaster risk reduction / [edited by] Ben Wisner, J.C. Gaillard and Ilan Kelman.* 1st ed. New York, London: Routledge. Available at: http://www.routledgehandbooks.com/doi/10.4324/9780203844236 (Accessed: 6 November 2020).

World Habitat Awards (2012) *World Habitat Awards | Innovation. Sustainability. Transfer.* Available at: https://web.archive.org/web/20120509102233/http://www.worldhabitatawards.org/winners-and-finalists/project-details.cfm?lang=00&theProjectID=D7AB9365-15C5-F4C0-99C3FFDB19A5E678 (Accessed: 2 June 2021).

Zhang, M. (2013) *The Semiotic Characteristics Research on Residence Architecture of Western Sichuan*. Master. Southwest Jiaotong University. Available at: https://kns.cnki.net/kcms/detail/detail.aspx?dbcode=CMFD&dbname=CMFD201401&filename=1013250462.nh&v=AieagvBu6hJ31kZCabkdXOi5lNTtBKzVglUKQLMprZNxbz%25mmd2F2rsvWbIO%25mmd2B5xUEZyc7 (Accessed: 25 February 2021).

Zhao, C. (2016) ‘My Understanding and Principles for the Country Revival of China’, *The Architect* [Preprint]. Available at: http://en.cnki.com.cn/Article_en/CJFDTotal-JZSS201605003.htm (Accessed: 30 September 2020).

Zhu, H. (2018) ‘WuXi Global Forum 2019’, *WuXi XPress: for WuXi news and R&D insights*, 12 December. Available at: https://wxpress.wuxiapptec.com/wuxi-global-forum-2019/ (Accessed: 18 July 2019).

Zhu, J. and Hu, M. (2011) ‘Multi-Governing: The Introspection of the Participatory Developing Theory in the Post-Disaster Reconstructions —— A Case Study of the “New Housing Plan” after the Wenchaun Earthquake’, *Open Times*, (10), pp. 5–25.

Zou, S. (2009) ‘The Functional Study of NGO——Seeing the Development of Chinese NGOs from the Wenchuan Earthquake’, *Marxism & Reality*, (03), pp. 66–68.

Zwerger, K. (2012) ‘Wood and wood joints building traditions of Europe, Japan and China’. Basel: Birkhauser.