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# A preliminary investigation of the rammed earth houses in a vernacular village in China

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**Abstract:** The current increasing speed of urbanization in China, is threatening to demolish highly significant vernacular buildings in rural areas. Based on this context, the character of vernacular architecture and the construction principles in the local area is the subject of this paper, specifically, their spatial arrangement, structure, enclosure, and other elements of a vernacular building will be summarized. In 2005, the Chinese government first proposed the "Beautiful Village" project, an upgrading plan to improve the life satisfaction of people living in rural areas. In 2013, the first author participated in surveying the historical development of *Yangyuan* Village, which is involved in the beautiful village project. To assess the village's typology and buildings techniques, the research project utilized a mixed methods approach that included interviewing villagers and craftsmen, photographing buildings, statistical analysis of the roof truss and computer modelling of vernacular buildings in order to understand the local vernacular construction principles. The vernacular buildings are argued to be ecologically and socially sustainable because of their use of local low-energy materials, traditional construction methods and forms which result from a long history. The paper identifies a typical building type and traditional construction system. We argue that constructing new buildings in traditional villages using the principles derived from their vernacular setting is a sustainable method for the development of villages in the future.

**Keywords:** China; vernacular village; traditional construction system; rammed earth; sustainable

## 1. Introduction

In recent years, the rapid pace of urbanization in China has had significant large-scale impacts on rural areas which are now confronted with new economic, social and environmental challenges (Ding, 2013). One consequence is that the young rural labour force typically migrates away from their hometowns to the burgeoning cities, seeking employment and financial success, which causes the rural population to diminish. Some of these rural villages have cultural heritage significance, which dates back to Ming (1368-1644) or Qing Dynasties (1644-1912). Meanwhile, a so-called "vernacular frenzy" is sweeping rural areas of China in recent years, in which the popularity of rural villages has increased and urban people have started to long for the country life. This may be caused by urban people wearying of modern reinforced concrete buildings in cities or suffering too much mental stress, and so seeking out rural villages and vernacular architecture as alternatives. The mass media and journal papers report there was a trend that architects have designed some modern, but vernacular style, hotels to attract visitors to these areas (Ying & Zhou, 2007). However, a majority of these new buildings in rural villages are typically constructed using reinforced concrete but visually mimicking the vernacular style, and did not conform to sustainable design principles or use vernacular materials and techniques. In the long run, the villages themselves would slowly lose their specific character and craft of vernacular constructions if this development continues.

The theory of vernacular architecture existed as early as the 19$^{th}$ century. In fact, vernacularism has a potential connection with building in British linguistics in the 17$^{th}$ century (Gabriel, 2006). It was not until 1818 that vernacular architecture developed into an explicit term (Oliver, 1997).

In 1976, the International Council on Monuments and Sites (ICOMOS) founded a committee to promote studying and research on vernacular architecture, and in *Charter on the Built Vernacular Heritage*, defined “Vernacular Building” as “the traditional and natural way that community residents build houses for themselves.” There are six standards for the identification of vernacular architecture (ICOMOS, 1999):

*“1. A manner of building shared by the community*

*2. A recognizable local or regional character responsive to the environment*

*3. Coherence of style, form and appearance, or the use of traditionally established building types*

*4. Traditional expertise in design and construction which is transmitted informally*

*5. An effective response to functional, social and environmental constrains*

*6. The effective application of traditional construction systems and crafts”*

Prior to this, in 1964, The Venice Charter, pointed out the importance of reuse in the historical building conservation practice, in article 5, maintaining that “the conservation of monuments is always facilitated by making use of them for some socially useful purpose” (ICOMOS, 1964). Adaptive reuse was clearly put forward as a way of maintaining the physical fabric of important cultural sites when their economies and circumstances change, in this very influential heritage management document.

The Venice charter is not without its critics, however, including the former head of the historic-buildings group in Public Works, New South Wales, Peter Bridges, who claimed that the Venice Charter was European-centered approach, in need of rewriting to fit with the local area being considered (Walker, 2014). Following this the Burra Charter, the Australia ICOMOS Charter for Places of Cultural Significance was published in 1979. It emphasized the concept of significance, apart from a building’s value in utilization, and recognized the values of community and place, as well as the physical fabric (Australia ICOMOS, 2013). These theories and charters are discussed later in reference to the historical buildings and sites examined here.

Compared to historical architecture, vernacular architecture is folk style, and the vernacular focus is on recognizing traditional construction skills and local materials. Typical vernacular architecture is defined as built by the inhabitants, with local materials and traditional technologies, and maintains the regional cultural significance, and so few authors discuss contemporary vernacular styles. However, at times indigenous people themselves do adapt and update their building techniques using new materials that become available, or in response to changing circumstances. This continual change reminds us that vernacular architecture is not static and that vernacular styles can be modified with the passing of time.

## 2. Objectives

The boundary of the concept of stainability is expanding in recent academic discussion. Generally, it can be divided into four aspects: cultural, social, economic and environmental sustainability (Boström, 2012; Chiu, 2004; Connelly, 2007). All these sustainable factors can be seen in a construction process of vernacular building.

Vernacular construction skills and their associated intangible cultural values should be protected and transferred to next generation. However, not many youngsters seek to learn these because of the small income and lack of work for traditional craftsmen. The construction process for vernacular buildings is related to the whole community, so it is a social event. Furthermore, the organic material typically used for vernacular building activities mainly comes from local sources, so there is no doubt that the economic and environmental aspects of these vernacular architecture is usually excellent.

The objectives of the paper are to record the character of vernacular buildings, the construction skills required and illustrating how these vernacular buildings are built in each part or element in order to educate our descendants how these rammed earth buildings were constructed in North Fujian. Specifically, the characters and construction process including the foundation, rammed earth wall, timber structure, stair case, windows and doors. In the end of the paper, there summarizes a typological unit as a guide for future design for the buildings share the similar characters in these area.

## 3. Project information

In May 2013, *Zhenghe* County of Fujian Province joined the “beautiful village” upgrading plan, which aims to enhance the living conditions, infrastructure construction, environmental protection, and the economy of the rural areas. As one of the earlier pilot villages in the plan, *Yangyuan* Village (27°09’N, 119°00’E) preserves hundreds of ancient dwellings built in the late Ming Dynasty and early Qing Dynasty, which are the most intact and typical old house compounds in the northeast region of Fujian Province. Entrusted by the local government, the team of Professor Chen Zhao, of Nanjing University, developed a proposal for the planning, overall design, and design of individual residences within the ancient village to accord with its original morphology, making it a revitalized village integrating cultural significance and natural landscape (Luo & Zhao, 2015). The next part of this paper will discuss the background and traditional construction skills investigated during the project.

Fujian Province is a mountainous region, and the poor traffic connections are one of the main reasons for its undeveloped economy. *Yangyuan* Village, an easternmost village of *Zhenghe* County is located in the middle of Fujian Province, originally named *Huangyuan* Village, was first constructed by a family surnamed Zhang in 889. The village is located on the southeast slope of the valley between *Feng* Mountain and *Donggong* Mountain, with the relief inclining slightly to the southeast and the average elevation above 800m. The highest temperature in *Yangyuan* is 34.7℃, the lowest -12.2℃, and the average 14.7℃. With the diurnal temperature difference, it has the typical climate of “Northern China”. Culturally significant relics include *Yingjie* Temple built in the first year of Emperor Kangxi (1654-1772) of Qing Dynasty, *Shuiweicuo* Bridge built in the first year of Emperor *Xianfeng* (1851-1861) of Qing Dynasty; scenic spots include the Carp Stream, which was prosperous in the years of Emperor Jiaqing and divided the ancient village into the southern and northern parts, where numerous carp can be found swimming in groups.

In 2012, the *Ningwu* Expressway was open to high-speed traffic, passing through *Zhenghe* County and converging with *Guping* Expressway at *Yangyuan* Village (Figure 1). Therefore, *Yangyuan* County will become an important area that embraces the economic development driven by increased traffic.

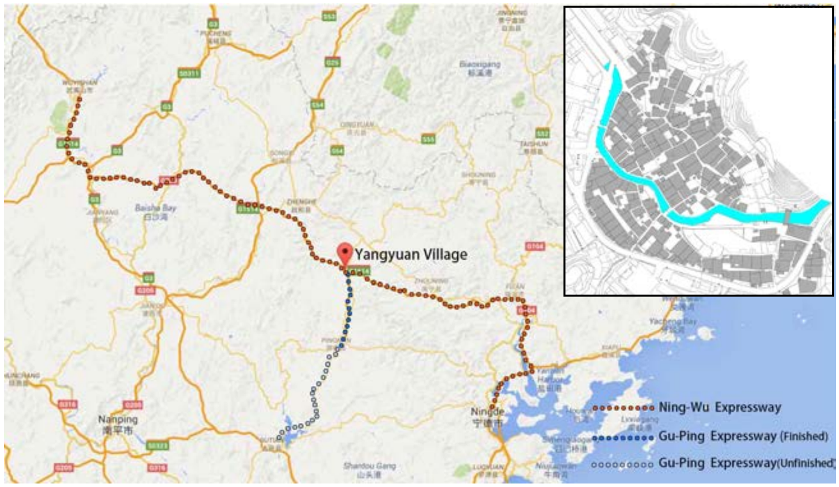


Figure 1: Map of Yangyuan and the context of the village (above right corner)

## 4. Methods

The research methods for the village analysis comprised of four parts: interviewing villagers and craftsmen, observing and measuring buildings, a statistical analysis of the village buildings' timber structure and roof truss, and computer modeling of the buildings for analysis.

In terms of interviewing, the research team lived in the village for a week and worked systematically to hear from local residents and builders to gather a thorough oral history of the village, including its history, economy, climate, social customs, techniques of vernacular building construction and the villager's suggestions on required infrastructure. Meanwhile, we examined the whole village street pattern and took numerous photos during the observing process. Twelve vernacular buildings were surveyed and measured in detail and forty buildings' roof structure data were collected by tape-measure and laser range finder. After returning to the University, all the vernacular building data was collected statistically in order to get to maximum, minimum and average size of each element of vernacular housing there. Based on the all the information above, and with an aim to define the typology of the village buildings, we use computer modelling to conclude the typical unit and define the "traditional construction system".

## 5. Observed details of the vernacular construction in the village

### 5.1. Stone foundations

For the humid and rainy climate in the mountainous area of Fujian Province, stone is used as the foundation of soil walls so as to isolate from moisture. Stone foundations fall into two types: large footings (an underground foundation trench) and small footings (where the wall is above the ground). In the large footing, constructors first excavate the foundation trenches ranging from 60cm to 200cm deep. Foundation trenches are usually twice the width of small footing. After the excavation of foundation trenches, constructors need to cushion the wall foundation and build wall toes with one or two rows of large stones. If the foundation is soft or subject to flooding, the excavation is made deep enough to reach a solid base; wall foundations can be built with large sized gravel, whose biggest surface should be downward, and their joints are filled with small sized gravel. After wall foundations are built above ground, small footings are constructed using one of three methods: dry masonry, wet masonry, or the "gold wrapping silver" technique, which we go on to explain. Dry masonry refers to constructing a small footing with unprocessed large round river stones on two sides, with the middle cushioned with small rubble. Wet masonry refers to constructing a small footing with rock blocks and cement. "Gold wrapping silver" refers to the small footing being built with one or two layers of stones (about 60cm thick), and the middle part is tamped with red soil or other clays. The wall built with stones accounts for about 35% of the total thickness (Chen, 2012).


Figure 2: Stone foundation types

Because of the side forces coming from two directions, materials at corners are usually hard and intact, or cut square stones or bricks. Sometimes, these stones are longer than the standard level of stones, rising above to the lowest point of the soil walls. The construction of corners is similar to staggered joints of brickworks, rather than X-shaped joints with 45° inclined stone in the non-corner area (Figure 2). Broken stones or bricks are usually used to produce a flat plane for the sake of tamping soil walls in the future.

## 5.2. Rammed earth wall

Dwellings in Fujian Province are still constructed using a unique rammed earth wall method. Two horizontal planks are erected in parallel, to create a form work for the wall thickness. These clamping planks are supported with external clamping posts, and then earth is filled between the two planks and stamped tightly. Finally, the wall is formed after the removal of planks and posts.

Fujian Province has locally grown fir trees, which are used as material for dwelling structures and ramming tools in the mountainous area of the northern Fujian, including wall frames, bulkheads, clamping posts, clamping planks, etc. (Figure 4). Wall frames are usually 2.5-3.5m high and 30-50cm wide, which is equivalent to the rib plate of a bulkhead. Bulkhead and clamp planks are about 5-7cm thick. The two side edges of a clamping plank are vertical, and the end is fixed with a bulkhead. The other side is opened and connected with the rammed wall, and fixed with blocking woods. Then, the earth is filled for ramming to form the minimum unit of a rammed earth wall, namely a "Ban". After compression the earth comprising the wall is half its original volume. After the completion of one template and the removal of clamping planks, the wall surface should be finished. The wall surface is then beaten strongly to make it solid and then gently to flatten it. Bamboo chips soaked in water are added to the earth during the ramming, similar to rebar in reinforce concrete, they serve as reinforcements in the construction. When withdrawing the blocking woods, the earth is rammed to the required length, the template is raised and then the next layer is made using the same method. The rain and humidity are enemies to the life of rammed earth. The top surface of the rammed earth wall is usually covered by tiles and corbelling eaves to stop the rain erosion of the vernacular buildings. And the moisture sometimes that absorbed by the rammed earth may not be that bad, because slight increase (<4% by weight) in moisture will not lead to the drop of the rammed earth (Bui, Morel, Hans, & Walker, 2014).

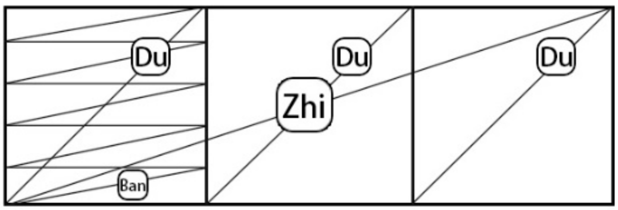


Figure 3: Module of rammed earth wall


Figure 4: Earth wall ramming tools

Modular rammed earth construction is recorded in ancient China as early as 770 B.C. to 221 B.C. We can find units such as "*Ban*", "*Du*", and "*Zhi*" (Figure 3) in *Rites of Zhou*, *Chronicle of Zuo*, and *Commentary of Gongyang*. *Du* is a section of wall formed after ramming in a vertical direction, usually 7-10 *Ban* in Fujian Province, the common modules of rammed earth wall. Correspondingly, *Ban* and *Zhi* are the sub-module and expanded module of the dimension of rammed earth wall respectively (Chen, 2012). Eight workers can ram two *Du* of earth wall each day with this method, and the second layer of earth wall can be started after the preceding layer is thoroughly dried within 60-80 days, according to local masters. Traditional buildings in China have two directions of width and depth. Earth walls can be defined as eave wall and gable wall corresponding respectively to width and depth direction. The gable wall of a principal room possesses the striking features, and the following are its six most commonly found styles (Figure 5). Eave walls following one of two types, depending on whether the second-layer wood structure has any projection (Figure 6).

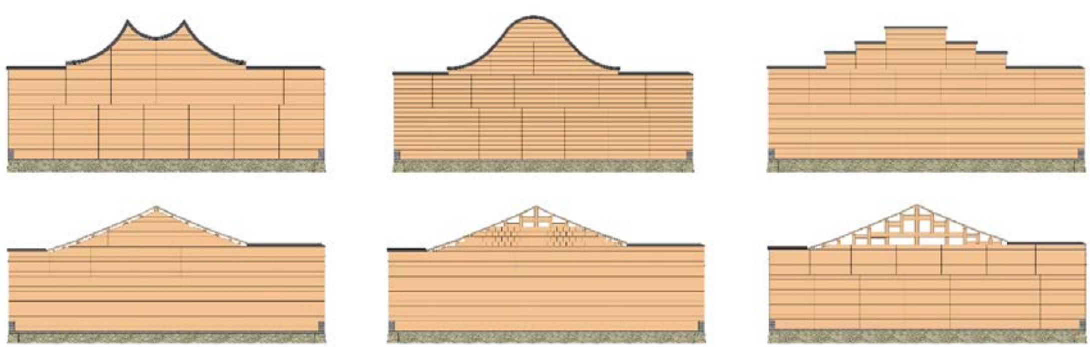

Figure 5: Gable wall style

Figure 6: Eave wall style

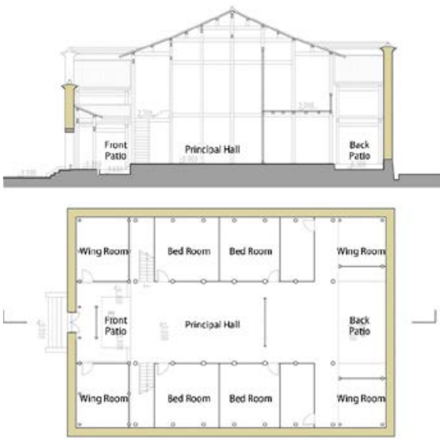


Figure 7: Plan and section of a typical unit

Figure 8: Principal hall

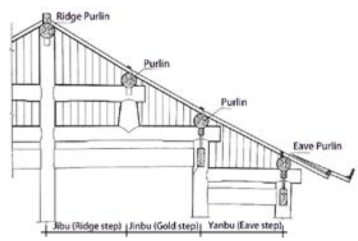


Figure 9: Name of *Bujia*

## 5.3. Timber structure

Dwellings in the mountainous areas of the north Fujian Province follow a typical form and structure: a courtyard behind the gate, with wing rooms at two sides separately (Figure 7). Wing rooms are lower than the principal room and are used for placing sundries. Sometimes, two stories are enclosed to form a small room. Behind the courtyard is the hall of the principal room (Figure 8). The size of a hall can be described by the number of pillars flanking the sides of hall, for example "four-pillar halls", "five-pillar halls", and "six-pillar halls". A hall is usually two stories, with an exposed roof truss. The two sides of a hall are bedrooms. Memorial tablets of ancestors or deities are consecrated in front of the wooden partition in the middle of the hall. There are doors at the two sides of the wooden partition leading to the rear room, which is often used as the kitchen. The rear courtyard is usually small, and a small tank is built there for collecting rainwater, washing vegetables, and raising fish.

In the timber structure buildings, the horizontal space between two purlins is called "*Bujia*" (Zhao, 2015). It is also known as a "*Jia*" or "*Chuanjia*". Two steps are considered one "*Bu*" in ancient times, which is an abbreviation for "*Bujia*". The unit of length for this varied in different dynasties. According to the arrangement of purlins, a timber structure is divided into several *Bujia*. The *Bujia* at the two sides of the ridge are called "*Jibu*"; those at the inner side of eaves are called "Yanbu"; and those between "*Jibu*" and "*Yanbu*" are called "*Jinbu*"(Figure 9).

We mapped and surveyed roof trusses of nearly 40 dwellings, and obtained the maximum, minimum, and average values of each *Bujia* in the region as follows (Table 1).

Table 1: Statistics of *Bujia* Values (mm)

| | Principal Room | | | Wing room | | |
|---|---|---|---|---|---|---|
| | *Yanbu* | *Jinbu* | *Jibu* | *Yanbu* | *Jinbu* | *Jibu* |
| Minimum value | 510 | 700 | 700 | 400 | 700 | 700 |
| Maximum value | 1500 | 1050 | 1100 | 1100 | 1260 | 1340 |
| Average value | 798 | 923 | 948 | 704 | 1040 | 980 |

## 5.4. Other Elements

Door frames are formed with embedded timber, bricks or stones incorporated in the process of module ramming, and most window frames are timber (Figure 10). Usually, the openings are along with the edge of a piece (*Du*) of rammed earth.

Figure 10: Door and Window Openings on Rammed Earth Wall

Dwellings in the region are predominantly two stories, and staircases are usually in the middle of the wing room and principal room (there may be staircases leading to the upper level behind the wooden partition of the hall of the second story and corridors at the two sides of the principal room). According to our survey, staircases have of these following types, and the key to staircase design lies in the treatment of different levels of the corridors at the two sides of the principal room and wing room (Figure 11).

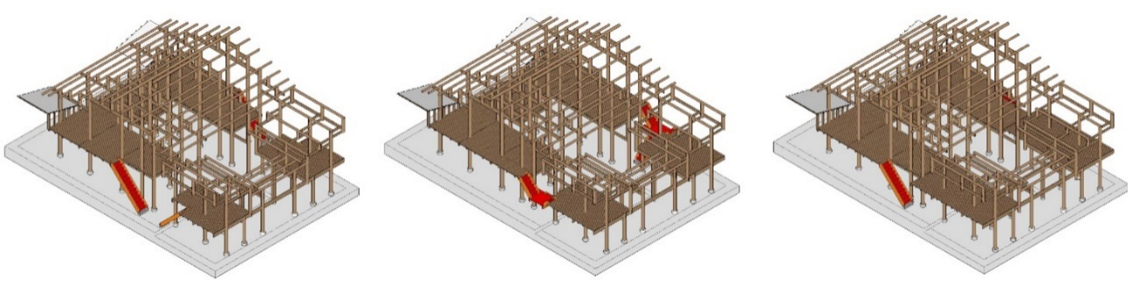

Figure 11: Staircase treatment

## 6. Results

Dwellings in the region mostly use earth as building enclosure material that provides outstanding performance for heat thermal isolation and timber as structure can easy to adapt different geographical terrace. Through the survey on local dwellings by the typological method, and after item research at the level of construction, we preliminarily abstracted a set of standard typical unit of the traditional construction system (Figure 12) as the basis of preserving these traditional features and continuing the style of the village in the design of new dwellings. This model gives evidence of enduring the test of time and therefore could reliably be used as a typological guide for future sustainable designs or extensions for that region.

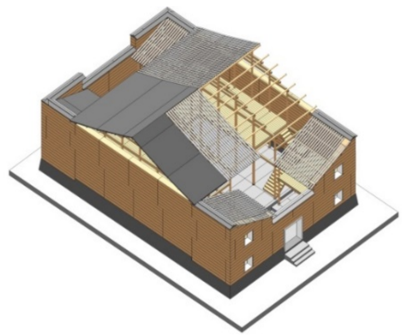

Figure 12: The typological unit of vernacular building

## 7. Discussion

In the field of architecture, the loss of cultural identity is a world-wide problem. In China, traditional villages are diminishing at an amazing speed. In order to conserve the cultural heritage and improve the living quality, the Chinese government propelled the "beautiful village" plan aims to lead the development of vernacular villages in a sustainable way. In this paper, we summarized the detail of vernacular construction that was observed in the village and identified a type and the "traditional construction system" of *Yangyuan* Village, albeit it is not illustrated in detail. This investigation and analysis application process can be used as a method for identifying, learning and defining a village building typology in any settlement around the China or even the world.

Since the approach that used to build the rammed earth building last for centuries, it should be assumed that the construction skill is suitable for use to build new housing there and it is of great intangible cultural and architectural heritage value to sustain the local skills. At a higher level, the morphological sustainability is a sub class of cultural sustainability. Therefore, not only the single vernacular building requires protection and adaptive renovation, but the morphology of the whole village also requires such consideration. The building type can give us an original model to be modified into variants for future design work to sustain the village morphology. In addition, we expect in the future that villages can support more employment, and attract migrant labor currently in cities back to their hometowns, so as to keep the balanced development of urban and rural areas. In that way, the social sustainability would operate functionally.

To conclude, selectively using recyclable materials and the original construction principles to reuse existing vernacular housing or reconstruct a new vernacular building, and respecting the pattern of the village's original morphology should be not only an eco-friendly and renewable, but also a social and cultural sustainable way of development of rural villages.

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## Reference

Australia ICOMOS. (2013) The Burra Charter: The Australia ICOMOS Charter for Places of Cultural Significance (pp. 1–10). Burra. http://doi.org/363,690994 ICO

Boström, M. (2012) A missing pillar? Challenges in theorizing and practicing social sustainability: introduction to the special issue. *Sustainability: Science, Practice & Policy*, *8*(1), 3–12.

Bui, Q.-B., Morel, J.-C., Hans, S. and Walker, P. (2014) Effect of moisture content on the mechanical characteristics of rammed earth. *Construction and Building Materials*, *54*, 163–169. http://doi.org/http://dx.doi.org/10.1016/j.conbuildmat.2013.12.067

Chen, X. (2012) *Studies on the Fujian Earth Fort AS A Case of Chinese Traditional Rammed Earth Construction System*. Nanjing Univeristy.

Chiu, R. L. H. (2004) Socio-Cultural Sustainability of Housing: AConceptual Exploration. *Housing, Theory and Society*, *21*(2), 65–76.

Connelly, S. (2007) Mapping Sustainable Development as a Con- tested Concept. *Local Environment*, *12*(3), 259–278.

Ding, W. (2013) Urban design needs urban morphology: a practitioner's viewpoint. *Urban Morphology*, *17*(2), 120. Retrieved from http://sfx.unimelb.hosted.exlibrisgroup.com/sfxlcl41?sid=google&auinit=W&aulast=Ding&atitle=Urban design needs urban morphology: a practitioner's viewpoint&title=Urban morphology&volume=17&issue=2&date=2013&spage=120&issn=1027-4278

Gabriel, A. (2006) What is vernacular architecture? Retrieved June 20, 2016, from http://ethnoarchitecture.org/web/articles/article/20060110-01a/

ICOMOS. (1964) International Charter for the conservation and restoration of monuments and sites (The Venice Charter 1964). In *IInd International Congress of Architects and Technicians of Historic Monuments* (pp. 1–4). Venice.

ICOMOS. (1999) Charter on the Built Vernacular Heritage. Mexico.

Luo, H. and Zhao, C. (2015) Outlining Principles of the Revitalization of Southern Chinese Villages: A Case Study of Pingnan Beicun in Fujian and Beyond. *Architectural Journal*, (09), 001–008.

Oliver, P. (1997) *Encyclopedia of vernacular architecture of the world*. (P. Oliver, Ed.). Cambridge: Cambridge University Press.

Walker, M. (2014) The Development of the Australia ICOMOS Burra Charter, *2*(5), 293–299.

Ying, T. and Zhou, Y. (2007) Community , governments and external capitals in China ' s rural cultural tourism : A comparative study of two adjacent villages, *28*, 96–107.

Zhao, X. (2015) *A Study on the Development Process of the Prototype of the Traditional Chinese Wooden Framework on the Basis of "Jian Jia."* Nanjing University.