Establishing and applying a value evaluation model for traditional Pit Kiln villages in the Henan province of China

Shaohua Zhu*, Byungsook Choi† and Chunwon Kang‡

*Department of Environmental Design, Northeast Electric Power University, JiLin, China; †Department of Housing Environmental Design, Jeonbuk National University, Jeonju-si, Jellabuk-do, Korea

ABSTRACT
The pit kiln in western Henan is a relatively unique architectural form. With the development of society, pit kilns are facing the dilemma of existence and development. This paper assesses the architectural value of six pit kiln villages in the western part of He’nan Province, China, aiming to explore the methods of traditional building value evaluation, and proposes the evaluation framework and elements, and provides a basis for the judgment of village development planning. The research methods used were the statistical analysis (Dephi) and the analytic hierarchy process (AHP). The criterion level includes scientific, artistic, social, and use value, and among them, social value has the greatest weight. The sub-criterion level is composed of 15 elements, that is building age, structure, materials, coordination with the environment, representation of building technology, decoration, and form, building location, scale, and utilization rate, building layout, building interior environment, and building economy. Based on these criteria, the six villages assessed are divided into two levels: good and normal. The good villages are those that scored high because of their representative architectural form, good location and good conditions of usage.

1. Introduction
1.1. Research background
In 1995, American critic Roy Morrison clearly put forward the concept of ecological civilization. He believed that ecological civilization is a new form of civilization after industrial civilization (Morrison 1995) (Morrison 2007). The core of ecological civilization is the harmony between man and nature. It is not the starting point to meet the material needs of man, but it takes man and the natural environment as a unity. It emphasizes integrity and systemicity, so ecological civilization is more advanced and greater than industrial civilization that emerged during the development of human society. In an ecologically civilized society, the built environment is set up in harmonious relationship between man and nature.

Facing the environmental crises includes population growth, energy waste, and environmental quality decline, people are actively exploring the development and utilization of renewable energy, researching green technologies, and developing circular economy, architects have gained a renewed respect for nature and realized the importance of designing with nature in mind (Sharmin and Bilge 2013). One strategy for this is to learn from and re-creates aspects of vernacular architecture (urban buildings) from history that conform to the principles of passive energy conservation (Wu 1999) (Nguyen et al. 2019). Grasping the characteristics of vernacular architecture, does not require a deep knowledge of theory or particular aesthetic sensibility. Rather what is required is merely a practical understanding of that vernacular architecture is an architecture formed under the restriction of natural physical environment elements. (Rapoport 1969)

As one of the vernacular buildings, the raw soil building has become one of the most effective ways to realize green buildings because of its outstanding heat storage performance, reproducibility, low energy consumption during processing, and no pollution. (Fuentes Pardo and Guerrero 2006) Numerous raw soil architecture research institutions have been established in various developed countries and manifold international academic conferences focused on the research and protection of raw soil architecture. (Fernandes et al. 2019) Established in the last century, the international Center for Research and Application of Raw Soil (CRATerre-ENSAG) uses modern material science theories to optimize traditional raw soil-based materials to form modern raw soil materials that do not require chemical modifiers. The center provides an important theoretical basis for the research of the world’s modern soil basic materials and construction technology, (Houben, and Guillaud 2005) such as adobe architecture have been convened. Research on the protection and application of raw soil construction...
technology has been promoted in developing African countries. Due to the improvement of ecological awareness in developed countries, villas built with raw soil have become one way for people to return to nature. Since 1980, a large number of villas have been built with new adobe in France, the United States, Brazil and other countries. (Maniatidis and Walker 2008) (Heatheote 1995) (Minke 2006) Also, a variety of high-strength adobe machines have been promoted in developing countries in Africa.

In the 1980s, Chinese Professor Ren Zhenying proposed to study Chinese cave dwellings, influencing architects and scholars from architectural theory circles to begin to pay great attention to these dwellings. Japanese, French, Australian scholars and graduate students have visited China and achieved fruitful results in their study of cave dwellings.

Pit kilns, or “sunken courtyard houses” Figure 1, are one type of cave dwelling along with cliff kilns, and independent cave dwellings. The pit kiln is a type of building constructed by digging down from the flat ground to form a square or rectangular artificial courtyard, and then digging a cave deep in the artificially created four-walled cliff face, due to the large heat capacity of loess, the pit kiln has a better thermal environment, and the indoor can have a constant temperature effect. (Liu et al. 2011) (Wang and Liu 2002).

China’s pit kilns are mainly distributed in the Loess Plateau in the western part of Henan. The loess layer here is the most mature, with uniform soil quality, continuous extension, and good vertical structure, very suitable for caves. Before 1950, the residents in western Henan basically used the cave dwellings, but after 1970, the cave dwellings began to be gradually abandoned. After the 20th century, few people lived in the cave dwellings anymore, and a large number of pit caves were abandoned or landfilled. However, the decline of pit kilns stands in strong contrast with their status among research academia, who are enthusiastically advocating that the pit kiln should be studied as a rare earth-building structure, and the academia unanimously believes that the pit kiln has good research and preservation value. Through investigation, it has been found that different groups such as villagers, researchers (including designers and university teachers), and government managers all have different evaluations on the pit kilns. Villagers pay more attention to the practicality of the buildings, researchers focus on their artistic and scientific values, while government managers are concerned with their social values.

![Figure 1. The form of Pit Kiln (Sources: photograph by authors.)](image-url)
1.2. Research purpose

Facing the development of pit kilns, we must first evaluate their value. Only when such an evaluation is first completed, can it play a guiding role in the eventual transformation and utilization of the pit kiln. Preliminary research into pit kilns mainly includes a focus on their structure, materials, and physical environment. Up to this point, there has been no research on pit kiln development from the perspective of value evaluation. For this reason, this article takes up this perspective and seeks to uphold the positive elements of vernacular architecture in China and to utilize them in contemporary social projects, aim to provide designers and managers with judgment and a basis for the planning and development of six villages.

1.3. Research methods

This article uses methods from field and questionnaire surveys, to expert interviews, and develops the field survey data to carry out research. The research process was as follows:

(1) Conducting on-site investigations on traditional buildings in Sanmenxia City, extensively collecting materials, information, and accumulated basic data for follow-up work.
(2) Establishing, through a literature review, an evaluation index system for the building value of pit kilns.
(3) The comprehensive use and application of the Delphi and AHP methods.

The delphi analysis (Delphi) method centers on consulting experts in the field about problems, and having each expert assign a weight on an evaluation index. Then the average weight of each index is calculated, which is used as the final weight. This method is also called the expert assignment method.

The Analytic Hierarchy Process (AHP) was proposed by the American operations researcher T.L. Saaty in the 1970s. It is a relatively rigorous research method that quantitatively analyzes qualitative problems. The basic principle is to regard a complex problem as a system, according to the subordination relationship between the internal factors of the system. In turn the various elements of a complex problem are transformed into an orderly hierarchy. Elements at the same level use those of the previous level as criteria to construct a judgment matrix Figure 2. Afterwards, judgments are compared in pairs to calculate the weight of each element. Weight determinations often decided by a few experts based on their direct experience (Thomas 1977)(Thomas 2003).

The first step of our research was to combine the Delphi method with the AHP method to establish an evaluation model for pit kiln villages. Next the evaluation model was used to conduct a case study. Part of the data of the case study came from survey statistics, and part was obtained by using the Delphi method, which requires expert scores. The research process required the use of Excel software for data calculation.

1.4. Current status of research objects

From June 2020 to September 2020, a field survey was conducted on pit kilns villages in the Sanmenxia area of He'nan (34°34′N, 111°25′E). The survey results show that before 1950, all villagers lived in pit kilns. Since the 1960s, pit kilns were no longer built, and new houses were made with bricks on the ground. In 1970, the pit kiln retention rate was about 87%, but in 2019, the ratio fell to 26% (Data comes from local statistics department).

Meanwhile, the occupancy rate (the ratio of the number of dwelling caves to the number of existing cave dwellings) of pit kilns rapidly declined, as well. Before 1950, the occupancy rate was about 100%. After the 1970s, as people moved out of the pit kilns, most rural areas have been basically abandoned according to the data from the local statistics department. In 1970, the occupancy rate of pit kilns was about 95%,
2. Literature review

The United Nations Educational, Scientific and Cultural Organization (UNESCO) at the Convention for the Protection of the World Cultural and Natural Heritage in 1972 (UNESCO 1972), put forward corresponding standards for the evaluation of cultural heritage. In terms of buildings, it requires the selection of cultural heritage to have historical, artistic, scientific, and aesthetic representativeness and compliance with an authenticity standard (S. et al. 2002). Traditional buildings with a long history of settlements with typical empirical significance, as well as buildings related to important people and places of events are included in the scope of evaluation (K. et al. 2019).

The Nara Authenticity Document (1994) (UNESCO 1994) emphasizes the importance of the cultural background and environment in which a heritage is located and stated that both categories have a decisive influence on a value judgment. The Vernacular Architecture Heritage Charter (1999) (UNESCO 1999) bases its evaluation criteria on the traditional background of the vernacular culture, while it also seeks to affirm essential regional characteristics and establish the nature of a vernacular architecture as a new category of heritage that is different from traditional heritage protection (Ma, Li, and Chan 2018).

These international declarations mostly start from the perspective of architectural cultural protection, from focusing on single buildings to focusing on the overall protection of building groups and focusing more on cultural elements in evaluation. At the same time, some experts have also put forward their views on building evaluation, and they have increased their attention to the usability and psychological aspects of the residents. In 1992, Purcell & Nasar proposed an evaluation model of prototype perception, familiarity, appearance, and aesthetic experience from the perspective of environmental perception (Purcell and Nasar 1992). In 1995, Bass and Ligtendag conceived of the most important aspects of heritage value as typicality, scarcity, and consistency with the surrounding environment. Coeterier(Coeterie 2002), in 2002, proposed that the residents of heritage sites pay more attention to the form of the heritage. Coeterier’s evaluation criteria has four aspects: form, information, functional use, and emotional factors. The form can be subdivided into aesthetics, initial, uniqueness, and artistry. Mazzanti discussed, in 2003, the methods of heritage evaluation from the different perspectives of economy, cultural value, and residents’ attitudes (Mazanti 2003).

Australian professor Frederick Romberg (Prukin 2011) believes that historical architectural heritage should have the following values: 1) historical value, including scientific value and emotional value, 2) artistic value, including artistic historical value, artistic quality value and artistic value itself, 3) functional value. Russian professor O.N.Prukin (Prukin 2011), from the perspective of protection and restoration of historical buildings, thinks that architectural value should include: 1) historical value (determining historical authenticity), 2) urban planning value (related to historical urban planning), 3) architectural aesthetic value (display and determination of architectural aesthetics), 4) artistic perception value (art-feeling interaction), 5) scientific restoration value (building repairability), 6) functional value (integration with modern functions). Both Frederick and Prukin’s evaluations of buildings have added functional value to the project of defining value and the elements that comprise it. Various evaluation standards are summarized in Table 1.

In the evaluation of building value, it can be seen that most of the research results of previous scholars focused on the scientific, historical and artistic value of the building (Mari, Eir, and Nils 2011) (Morkunaite et al. 2019), which is mainly due to the fact that their building evaluations are mostly from the cultural heritage perspective. In contrast, insufficient attention has been paid to social value and use value. The feature that distinguishes the vernacular architecture from the cultural relics is that it is still used by the inhabitants, and it is still the place where people live and produce. It can be used and reused. Therefore, the use value of a building, as an evaluation of the functional value of the reuse of the building, reflects the interests of the owners and users of the building property. The social value is based on the overall urban and rural perspective, considering the status of vernacular architecture in the socio-economic system, paying attention to its planning and development. Based on previous studies, then, this article takes into account the evaluation angles of different social groups on the value of traditional houses and summarizes the value composition of traditional houses as scientifically as possible. We divide the value composition of traditional houses into scientific value, artistic value, social value, and use value.
Table 1. Different building value evaluation standards.

| Literature name & scholar name | Category | View/Perspective |
|--------------------------------|----------|-----------------|
| Convention for the Protection of the World Cultural and Natural Heritage (1972) | ①cultural background | authenticity |
| The Vernacular Architecture Heritage Charter (1999) | ②nature of vernacular architecture | the scope of heritage |
| Purcell, A.T., & Nasar, J.L. (1992) | ①prototype perception | environmental perception |
| Bass, H.G., & Litjendag (1995) | ①typicality; ②scarcity; ③consistency | environmental characteristics |
| Cocterie, J.F. (2002) | ①form; ②information; ③functional use | the sense of form |
| Mazanti M. (2003) | ①economy; ②cultural value | development and sense |
| Frederick Romberg (1997) | ③appearance ④aesthetic experience | protection and function |
| O.N.Prukin (1997) | ①historical value; ②urban planning value, ③architectural aesthetic value | protection, restoration and development |
| ④functional value | ⑥perception value, ⑦scientific restoration value | |

Summarized Categories

Scientific value: history, structure, materials, consistency with the environment
Artistic value: representation and unity of architectural crafts, decoration, and form
Social value: location, scale, and use
Use value: building structure, space layout, indoor environment, building economy

3. Determination of building evaluation standards

3.1. Selection of the expert group

Typical and representative expert members were selected, whose work is closely related to pit kilns. The expert group consists of 24 people, including: 6 designers, 5 college teachers, 3 government administrators, 4 engineers and 6 village committee directors. The designers are architects who have renewed, repaired, and transformed the pit kilns. College teachers are scientific researchers who have worked on the protection and utilization of pit kilns. Government managers are those who in charge of formulating the pit kilns development plan. The engineers have engaged in the construction of pit kilns and environmental monitoring. The director of the village committee represents the interests of local farmers. Detailed information of the expert group is shown in Table 2.

Table 2. Information of the Expert Group.

| Category            | Number (%) |
|---------------------|------------|
| Gender              |            |
| Male                | 14 (41.6)  |
| Female              | 10 (58.4)  |
| Profession           |            |
| Designer            | 6 (25.0)   |
| University teacher  | 5 (20.8)   |
| Government mangers  | 3 (12.5)   |
| Engineer            | 4 (16.7)   |
| Rural managers      | 6 (25.0)   |
| Career experience   |            |
| Below 3 years       | 2 (8.3)    |
| 4–10 years          | 10 (41.7)  |
| 11–15 years         | 8 (33.3)   |
| Above 16 years      | 4 (16.7)   |
| Average             | 14.8 years |
| Total               | 24(100.0)  |

3.2. Determination of the evaluation standard system

The Delphi method and the AHP were used to determine the level of the evaluation system and construct the framework for the evaluation system for the pit kiln building value. The complete analytic hierarchy model is a hierarchical structure, which consists of several main parts: the target level, the criterion level, and the sub-criterion level Figure 2. According to the principles of comprehensiveness, representativeness, quantification, relevance, and comparability, the evaluation elements were selected. The main characteristics of the evaluation elements must reflect the self-value characteristics of the pit kilns, and pay attention to authenticity, integrity, and environmental quality (Ribera et al. 2019).

The target level is the evaluation of the building value of the pit kiln village. The second-level (the criterion level) is an evaluation index, which is based on previous studies Table 1, taking into account the evaluation angles of different social groups on the value of traditional houses. Thus, the value composition can be
divided into four parts: scientific value, artistic value, social value, and use value.

When determining the evaluation element of the third-level (the sub-criterion level or alternative level), 24 experts were consulted, and they listed the evaluation elements according to the evaluation index of the criterion level. Based on the opinions of those experts, the evaluation elements were summarized and sorted, and the results are as follows:

The scientific value contains 4 elements, namely, the age, the rationality of the building structure, the quality of building materials, and the adaptability of the building to the environment. The artistic value is composed of 4 elements: the integrity of the building shape, the representativeness of architectural decoration, the typicality of building craft, and the typicality of architectural modeling. The social value has 3 elements, including location conditions, scale of the building group, and usage rate. The use value comprises 4 elements, specifically, the safety of the building structure, the rationality of the spatial layout, the suitability of the indoor environment, and the economics of construction. The evaluation system of the pit kiln building value is shown in Table 4.

3.3. Establishment of evaluation standard

According to Likert scale evaluation, it is divided into 5 levels, corresponding to different evaluation elements, formulating specific evaluation standards. The construction age(A1) is divided according to the construction age of the pit kilns, the building group scale(C2) is distributed along the lines of the number of pit kilns per unit area, and the utilization rate(C3) is allocated according to the state of use of the existing pit kilns. The other elements are divided according to the degree of difference. As shown in Table 3.

3.4. Determination of evaluation index weight

The role of the evaluator is compared with the index of each level in pairs, according to T. L. Satty 1–9 scale method and give points according to 1, 2, 3...9 and 1/9, 1/8...1/2, 1, to measure the importance of each. 1, 2, 3...9, 1/9, 1/8...1/2, indicate the difference in importance when comparing two elements (i, j) (Thomas 2003). 1 means that two elements are equally important, 3 means that one index (i) is slightly more important than the other (j), 5 is obviously important, 7 is strongly important, and 9 is extremely important. 2, 4, 6, 8 are the intermediate values of the above judgment, 1/9, 1/8...1/2, 1 corresponds to the degree of importance of the index(j) and not the index (i).

In this way, numerical values can be used to quantify the relationship between different indicators to form a judgment matrix at each level. By calculating the average score of 24 experts, the judgment matrix can be obtained. According to the sum-product method, first obtain the eigenvector of the judgment matrix, and then calculate the maximum eigenvalue (λ max. From there, calculate the consistency index of the judgment matrix (C.I.) . Once this is completed, calculate the random consistency ratio (C.R.) . When C.R.<0.10, the judgment matrix is considered to have acceptable consistency, with the eigenvector as the weight value of an index. The result generates an evaluation model Table 4.

At the criterion level the weight of the scientific value (A) was 0.26, and the artistic value (B) was 0.25, placing them in the middle range. The weight of the social value(C) was 0.34, and the weight of the use value (D) was 0.15. The social value(C) scored the highest, while use value (D) scored the lowest.

In the evaluation factor layer, for the category of scientific value, the weight of the year of construction (A1) was 0.14; the weight of the rationality of the building structure (A2) was 0.41; the weight of the quality of building materials (A3) was 0.19; the weight of the architecture and environmental adaptability (A4) was 0.26.

In the category of artistic value, the weight of the integrity of the architectural shape (B1) was 0.14; the weight of representative architectural decoration (B2) was 0.19; the weight of typicality of building craft (B3) was 0.23; the weight of typicality of architectural modeling (B4) was 0.44. In the social value category, the weight of location conditions (C1) was 0.44; the weight of building group scale (C2) was 0.41; and the weight of usage rate (C3) was 0.15. Under the use value category, the weight of the safety of the building structure (D1) was 0.36; the weight of the rationality of the spatial layout (D2) was 0.29; the weight of the indoor environmental suitability (D3) was 0.19; and the weight of the economics of the construction (D4) was 0.15.

Among the total weights of index elements, the order with the higher weights are as follows: location conditions (C1, 0.15); building group scale (C2, 0.139); and rationality of building structure (A2, 0.107). The order of the lower weights are: economics of the construction (D4, 0.024); indoor environmental suitability (D3, 0.029); and integrity of the building shape (B1, 0.035).

4. Case study of Pit Kiln villages

4.1. Status survey of six villages

Traditional pit kiln villages are mainly distributed on the broad plateau in the middle and upper reaches of the Yellow River, with an average elevation of about 1200 m, which is where pit kilns are the most abundant and complete. The scope of this study is limited in location to the western Henan province of China, featuring Miaoshang Village, Liusi Village, Guanzhaitou Village, Qu Village, Yaodi Village and Beijing Village Figure 3.
Table 3. The standard of evaluation.

| Evaluation elements | 5 | 4 | 3 | 2 | 1 |
|---------------------|---|---|---|---|---|
| Scientific value A  |   |   |   |   |   |
| Year of construction A1 | Before 1644 AD (Ming dynasty) | 1644–1910 AD (Qing dynasty) | 1910–1949 AD (Republic of China) | 1949–1980 AD (Before China's reform and opening up) | After 1980 (After China's reform and opening up) |
| Rationality of building structure A2 | Very good | Good | Normal | Bad | Very bad |
| Quality of building materials A3 | Very good | Good | Normal | Bad | Very bad |
| Architecture and environmental adaptability A4 | Very good | Good | Normal | Bad | Very bad |
| Artistic value B |   |   |   |   |   |
| Integrity of the building complex B1 | Very good | Good | Normal | Bad | Very bad |
| Representative architectural decoration B2 | Very good | Good | Normal | Bad | Very bad |
| Typicality of building craft B3 | Very good | Good | Normal | Bad | Very bad |
| Typicality of architectural modeling B4 | Very good | Good | Normal | Bad | Very bad |
| Social value C |   |   |   |   |   |
| Location condition C1 | Traffic condition is very good | Traffic condition is good | Traffic condition is normal | Traffic condition is bad | Traffic condition is very bad |
| Building group scale C2 | Pit kiln number is above 5/ha | Pit kiln number is 3–5/ha | Pit kiln number is 1–3/ha | Pit kiln number is 0.5–1/ha | Pit kiln number is below 0.5/ha |
| Usage rate C3 | Above 70% | 40–70% | 20–40% | 5–20% | Below 5% |
| The rationality of spatial layout D1 | Very good | Good | Normal | Bad | Very bad |
| The rationality of spatial layout D2 | Layout of space is very rational | Layout of space is rational | Layout of space is normal | Layout of space is rational | Layout of space is very unrational |
| Indoor environmental suitability D3 | Lighting, temperature, humidity are very good | Lighting, temperature, humidity are good | Lighting, temperature, humidity are normal | Lighting, temperature, humidity are bad | Lighting, temperature, humidity are very bad |
| Economics of construction D4 | Very low cost | Low cost | Normal | High cost | Very high cost |
Table 4. The evaluation model of Pit Kiln village.

| The target level | The criterion level | Index value | The sub-criteria level | Index element weight | Total weight of evaluation elements |
|------------------|---------------------|-------------|------------------------|---------------------|-----------------------------------|
| Evaluation of building value of pit kiln | Scientific value | 0.26 | Year of construction A1 | 0.14 | 0.036 |
|                  | A                   | 0.41 | Rationality of building structure A2 | | |
|                  |                     | 0.19 | Quality of building materials A3 | | |
|                  |                     | 0.26 | Architecture and environmental adaptability A4 | | |
| Artistic value   | B                   | 0.25 | Integrity of the building complex B1 | 0.14 | 0.035 |
|                  |                     | 0.19 | Representative architectural decoration B2 | | |
|                  |                     | 0.23 | Typicality of building craft B3 | | |
|                  |                     | 0.44 | Typicality of architectural modeling B4 | | |
| Social value C   |                     | 0.34 | Location condition C1 | 0.44 | 0.150 |
|                  |                     |       | Building group scale C2 | 0.41 | 0.139 |
|                  |                     |       | Usage rate C3 | 0.15 | 0.051 |
| Use value D      |                     | 0.15 | Safety of building structure D1 | 0.36 | 0.09 |
|                  |                     |       | The rationality of spatial layout D2 | 0.29 | 0.044 |
|                  |                     |       | Indoor environmental suitability D3 | 0.19 | 0.029 |
|                  |                     |       | Economics of construction D4 | 0.16 | 0.024 |

(*The C.R. of the five judgment matrices are as follows: (A1,A2,A3,A4)judgment matrix's C.R. = 0.0016, (B1,B2,B3, B4)judgment matrix's C.R. = 0.085, (C1,C2,C3,)judgment matrix's C.R. = 0.0001, (D1,D2,D3,D4)judgment matrix's C.R. = 0.027. All C.R.<0.10.)*

Figure 3. The location of six villages.

As of July 2020, Miaoashang Village has a population of 998 people and a total of 81 pit kilns, mostly constructed around 1960. Liusi Village currently has a population of 2,187 people and a total of 235 pit kilns, 62 erected during the Qing Dynasty, 28 at the beginning of the founding of the People’s Republic of China (1949), and 137 after the 1960s. The population of Guanzhaitou Village is 397 people and it has a total of 14 pit kilns, mostly built around the 1960s. Qu Village has a population of 1,560 people and a total of 54 pit kilns, many of them also constructed in the 1960s. Yaodi Village has a population of 1,419 people and a total of 50 pit kilns, most of them were built in the 1920s and a few were built in the 1960s. Beiying Village has a population of 968 people with a total of 80 pit kilns, mostly built in 1960s Table 5.

Except for the pit kilns in Miaoashang Village and Beiying Village, which are well preserved and some of them are even in use for tourism, the pit kilns in other villages are mostly abandoned. According to chronological data, the pit kilns in six villages disappeared at a rate of almost 50% from the 1980s to 2015, from 2015 to 2020 even faster, reaching 60%.

Table 5. Basic situation of the Pit Kilns in each village.

| Village Situation | Miaoashang Village | Guanzhaitou Village | Qu Village | Liusi Village | Yaodi Village | Beiying Village |
|-------------------|--------------------|--------------------|------------|--------------|--------------|----------------|
| Population        | 998                | 2187               | 397        | 1569         | 1419         | 968            |
| Number of pit kilns | 81          | 235               | 14         | 54           | 77           | 80             |
| Number of inhabited pit kilns | 17 | 41          | 3           | 10           | 26           | 15             |

*The population data is as of June 2019
(Source: housing statistics of the Shannxian County Bureau of Statistics in July 2020)
4.2. Case study and analysis

The 6 villages were scored by 24 experts according to the evaluation criteria Table 4. A total of 144 scoring forms were issued and 144 were recovered, all of which were valid. The calculation method for the evaluation result statistics is as follows:

1) The score of each element at the sub-index level was averaged by the scores given by experts. The results are shown in Table 6, and the line chart of the comparison of evaluation elements is shown in Figure 4.

2) The index level scores were obtained by multiplying the elements of the sub-index layer. The results are shown in Table 7, and the line chart of the comparison of evaluation elements is displayed in Figure 5.

3) The score of the target level, that is, the comprehensive score of the village, was obtained by multiplying the elements of the indicator layer by the weight. The results can be viewed in Table 6, and the line chart for the comparison of evaluation elements is presented in Figure 6.

1) Analysis of the sub-criteria level elements

The statistical results show that in the construction year (A1), Liusi Village scored the highest (4.1), and Guanzhaitou Village scored the lowest (2.2). Liusi Village has a relatively long history and the preserved pit kilns reflect this with 235 existing pit kilns, 62 built in the Qing Dynasty and 28 at the beginning of

Table 6. The score of each element of the sub-index level.

| The level | The sub-criteria level | Mioshange Village | Guanzhaitou Village | Qu Village | Liusi Village | Yaodi Village | Beiling Village |
|-----------|------------------------|-------------------|--------------------|-----------|--------------|---------------|----------------|
| Scientific value A | Year of construction A1 | 2.8(0.101) | 2.2(0.079) | 2.3(0.083) | 4.1(0.148) | 3.6(0.130) | 2.8(0.101) |
| | Rationality of building structure A2 | 4.1(0.439) | 2.7(0.289) | 2.8(0.300) | 2.8(0.180) | 3.1(0.332) | 3.8(0.407) |
| | Quality of building materials A3 | 3.6(0.176) | 3.8(0.186) | 3.7(0.181) | 3.6(0.176) | 3.9(0.191) | 3.7(0.181) |
| | Architecture and environmental adaptability A4 | 3.3(0.224) | 3.2(0.218) | 2.9(0.197) | 3.9(0.265) | 3.1(0.211) | 3.9(0.265) |
| Artistic value B | Integrity of the building complex B1 | 3.8(0.133) | 2.1(0.074) | 3.2(0.112) | 2.3(0.081) | 3.0(0.105) | 3.1(0.109) |
| | Representative architectural decoration B2 | 4.1(0.193) | 2.2(0.103) | 3.0(0.141) | 2.2(0.103) | 2.7(0.127) | 3.7(0.174) |
| | Typicality of building craft B3 | 4.2(0.244) | 3.0(0.174) | 2.1(0.122) | 3.1(0.180) | 4.1(0.238) | 3.5(0.203) |
| | Typicality of architectural modeling B4 | 3.2(0.352) | 4.1(0.451) | 2.3(0.253) | 3.0(0.330) | 2.2(0.242) | 3.6(0.396) |
| Social value C | Location condition C1 | 3.5(0.525) | 2.4(0.360) | 2.8(0.420) | 2.9(0.435) | 3.1(0.465) | 3.7(0.555) |
| | Building group scale C2 | 3.2(0.445) | 3.6(0.500) | 3.1(0.431) | 2.1(0.292) | 2.8(0.389) | 4.1(0.570) |
| | Usage rate C3 | 2.7(0.138) | 3.3(0.168) | 3.0(0.153) | 3.1(0.158) | 3.9(0.199) | 2.9(0.148) |
| Use value D | Safety of building structure D1 | 3.8(0.205) | 3.0(0.162) | 2.9(0.156) | 3.7(0.200) | 2.6(0.140) | 3.7(0.200) |
| | The rationality of spatial layout D2 | 3.6(0.158) | 2.2(0.097) | 1.7(0.075) | 3.1(0.136) | 2.2(0.097) | 3.8(0.167) |
| | Indoor environmental suitability D3 | 4.2(0.122) | 2.7(0.078) | 3.9(0.113) | 2.8(0.081) | 3.1(0.090) | 3.9(0.113) |
| | Economics of construction D4 | 2.3(0.055) | 3.1(0.074) | 2.7(0.065) | 2.6(0.062) | 2.2(0.0528) | 3 (0.072) |

Figure 4. The score of each element of the sub-index level based on the Table 6.
the founding of the People’s Republic of China (1949).
In the rationality of the building structure (A2),
the scores of Miaoshang Village, 4.1, and Beiying Village,
3.8, are higher. The building structure in Miaoshang
and Beiying villages has benefited from the development
of tourism. Some pit kilns have been transformed,
strengthened, or repaired, while some are used for visiting
and others for homestay tourism. The building materials of all pit kilns were either adobe or brick and in turn the quality of building materials (A3), showed no important difference. In architectural and environmental adaptability (A4), Beiying Village and Liusi Village have the highest scores (3.9). The number of pit kilns in both villages is relatively high, and the external environment of pit kilns has not been damaged, with some areas even

The criteria level_value

| The criteria level | Village    | Guanzhaitou Village | Qu Village | Liusi Village | Yaodi Village | Beiying Village |
|-------------------|------------|---------------------|------------|--------------|---------------|----------------|
| Scientific: A(A1+ A2+ A3+ A4) | 0.9403 | 0.772 | 0.761 | 0.888 | 0.8632 | 0.954 |
| Artistic: B(B1+ B2+ B3+ B4) | 0.9213 | 0.802 | 0.628 | 0.6393 | 0.711 | 0.880 |
| Social: C(C1+ C2+ C3) | 1.108 | 1.029 | 1.000 | 0.885 | 1.053 | 1.270 |
| Use: D(D1+ D2+ D3+ D4) | 0.540 | 0.411 | 0.409 | 0.479 | 0.378 | 0.552 |

Table 7. The score of the elements of the index level.

| The target level | Miaoshang Village | Guanzhaitou Village | Qu Village | Liusi Village | Yaodi Village | Beiying Village |
|------------------|-------------------|---------------------|------------|--------------|---------------|----------------|
| Evaluation of building value of pit kiln | 3.510 | 3.014 | 2.802 | 2.947 | 3.008 | 3.660 |

Table 8. The score of the target level.

Figure 5. The score of the elements of the index level based on the Table 7.

Figure 6. The score of target level based on the Table 8.
having been newly built. The masonry buildings have also been kept away from the pit kiln complex, which has aided in bettering the environment of the pit kilns.

In the integrity of the building complex (B1), Miaoshang Village has the highest score (3.8), followed by Qucun Village (3.2). The pit kilns of the two villages are integrated and coherent, and the environmental features of the historical villages are faintly visible. Pit kilns in other villages are too scattered. Among the representative architectural decorations (B2), Miaoshang Village has the highest score (4.1), followed by Beijing Village (3.7). Beijing Village’s pit kilns have been rebuilt to meet the needs of tourism development, and are no longer remodeled in the traditional layout style. The pit kilns in Miaoshang Village have basically maintained their original features. The historical representation, then, is much stronger. Miaoshang Village is the highest (4.2) in the typicality of construction craftsmanship (B3), followed by Yaodi Village (4.1). Due to tourism needs, the two villages have successively maintained the pit kilns since 2000 and were able to retain the traditional craftsmanship. In the typicality of architectural style (B4), Guanzhaitou Village has the highest score (4.1). The village now holds the largest number of pit kilns. In turn, the preservation of different types of pit kilns are more abundant than other villages.

In terms of location (C1) Figure 3, Beijing Village scored the highest (3.7) followed by Miaoshang Village (3.5). These two villages are only a 30-minute drive from the city, while other villages are located further away from urban centers, and are separated by generally poor traffic conditions. Beijing Village scored the highest (4.1) on the scale of the building group (C2). The village has a large preserved concentration of pit kilns due to the construction of its tourist area. The highest utilization rate (C3) is Yaodi Village (3.9), where all pit kilns are used for dwelling.

The safety of the building structure (D1) is the highest in Miaoshang Village (3.8), followed by Beijing Village (3.7). This is mainly due to the frequent maintenance needed to meet the demands of tourism. Consequently, in terms of the rationality of the spatial layout (D2), the two villages also scored the highest. The indoor environment suitability (D3) score was generally good, indicating that the indoor environment of the pit kiln is pleasant. In building economy (D4), Beijing Village has a higher score, and Yaodi Village and Miaoshang Village have lower scores. The pit kilns in Guanzhaitou Village are mainly used for storage, which results in low maintenance costs. Yaodi Village and Miaoshang Village are both residential and have tourism needs creating relatively high maintenance standards.

2) The analysis of the sub-criteria level index

The scientific value score is obtained by the sum of A1, A2, A3, and A4. Among them, Beijing Village is the highest (0.954) and Qu Village is the lowest (0.761). The score of artistic value is obtained by the sum of B1, B2, B3, and B4. Among them, Miaoshang Village is the highest (0.9213) and Qu Village is the lowest (0.628). The social value score is obtained by the sum of C1, C2, and C3. Among them, Beijing Village is the highest (1.270) and Liusi Village is the lowest (0.885). The use value score is obtained by the sum of D1, D2, D3, and D4. Among them, Beijing Village is the highest (0.552) and Yaodi Village is the lowest (0.378).

Based on the above, according to the order of the scores, the final value of the six villages can be obtained, which is Beijing Village (3.660), Miaoshang Village (3.510), Guanzhaitou Village (3.014), Yaodi Village (3.008), Liusi Village (2.802), Qu Village (2.802) belonged to the general or slightly worse category.

5. Summary and conclusion

5.1. Summary

Understanding the process of comprehensively valuing vernacular buildings is a prerequisite for their protection and development. The regionality and diversity of these buildings shows that there is no unique vernacular building evaluation system and method. As the buildings have different purposes, the standards of their value evaluation assessment will have to be different. The process of value assessment should rely on specific evaluation models tailored to the specific case and issues at hand. In this article, we developed a method of building value evaluation applicable to determining the status of pit kiln villages in western China.

By accounting for the evaluation methods of vernacular architecture and the actual situation of pit kiln villages, a qualitative and quantitative method for the determination of the value of the pit kiln villages was proposed. Using the AHP and DEPdi methods, the analysis target was divided into four elements: scientific value, artistic value, social value and use value. These categories were then refined into the specific evaluation factors. Applying the AHP, we determined the weight relationship of each element. At the criterion level, social value had the greatest weight, while artistic value and use value weighted the least. At the evaluation sub-criteria level, the location of the village, the size of the building group and the rationality of the building structure were assigned larger weights while construction economics and environmental integrity of the building were weighted less. In sum, the object of value evaluation was the entire village and in turn the proportion of evaluation elements are concerned more with social status and the role of the area.
With the resulting evaluation model set up, we evaluated six villages in Sanmenxia City, western Henan Province. Among the six villages, Beiyang Village and Miaoshang Village ended up with the highest final scores due to their representative architectural form, good location and good conditions of usage. These villages also promoted tourism-based business activities, which have encouraged the protection and utilization of the pit kilns in these villages. In the other four villages, pit kilns are used mainly for housing or storage, which neither of which promotes the overall development of the village. To their credit, however, the quality of the building materials, the adaptability of buildings and the environment, and the utilization rate of the buildings in these villages is also outstanding.

Ultimately, Beiyang and Miaoshang Villages scored above average, but were not at an excellent level. The two villages can stand as relatively good representatives. From the perspective of integrating the various elements of vernacular architecture, the overall level of the pit kilns village in China is not high. This is because they are not built long enough, the scale of the building complex is not concentrated enough, the construction cost is high, and the location conditions are not superior enough. Moreover, the economic development of these rural areas is relatively backward, there has been insufficient attention from local governments, the inadequate of cultural awareness campaigns, and a lack of in-depth research in academia.

5.2. Conclusion

As a type of vernacular architecture, pit kilns have strong regional characteristics. While pit kilns are generally in decline, how to maintain the sustainable development of the village and build an ecologically civilized village has become a problem and the design has opened new prospects for research, preservation, and development of pit kilns.

To realize the sustainable development of the village, we must correctly handle the relationship between economic development, cultural continuity, and a good natural environment. As the largest physical entity in the village, architecture is an important part of realizing and influencing the sustainable development of the village. First, the perspective of architecture should be high, and it should be positioned from the relationship between urban and rural areas. Second, the function of architecture should be comprehensive. It not only has the function of residence, but also should be judged from the perspective of culture, art, and society. To excavate and protect the material and non-material culture of the countryside, and conduct a scientific evaluation of the value of the pit kiln building as well as villages.

Objective and scientific evaluation is necessary to realistically assess pit kilns, without exaggerating their advantages or overlooking their uniqueness. Above all, the evaluation process must be rational. In this process, it is necessary to pay attention to several factors, including the overall environmental construction of the village, the improvement of traffic conditions, and the expansion and diversification of the use of pit kilns.

This study has conducted a value evaluation of six typical existing pit kiln villages, and our results provide basic information helpful to decisionmakers and members of the public as they choose how to develop those villages. Our evaluation model and its results were based on the input from 24 experts. The subjective views of these experts could not be ignored as we determined index elements and weights. While this study does not provide specific development strategies and recommendations, we hope that in the future, these can be developed.

Disclosure of potential conflicts of interest

No potential conflict of interest was reported by the authors.

Notes on contributor

Zhu Shaohua is the associate professor at the Department of Environmental Design, Northeast Electric Power University, China. He is studying for Ph.D. degree at Jeonbuk National University, Korea. His research interests include the architectural history and culture, and development of rural intangible cultural heritage.

ORCID

Chunwon Kang http://orcid.org/0000-0001-7696-8649

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