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Comprehensive Assessment of Thermal Comfort and Indoor Environment of Traditional Historic Stilt House, a Case of Dong Minority Dwelling, China

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Abstract: The stilt house is one of the most representative of Chinese architecture among national minority traditional dwellings, most of which are located in mountainous regions whose climate is characterized by hot summers and cold winters. Moreover, it is widely distributed in Southeast Asian countries, such as Thailand, Laos, Cambodia, etc., as well as tropics like Hawaii, Guam. These kinds of dwellings have unique architectural aesthetics as well as high climate adaptability. However, because of their remote locations and rapid disappearance in urbanization, few studies have focused on their real indoor environment and thermal comfort. More studies were engaged in their architectural aesthetics and space patterns. In this study, based on the measurement and evaluation of residential natural lighting, ventilation, air quality, and thermal comfort in traditional stilt Dong village houses, the air temperature, humidity, CO_2 and $PM_{2.5}$ concentrations, wind speed, direction, and other variables are monitored and analyzed. Results show that the inhabitants have a higher thermal comfort adaptation than urban residents under natural ventilation. Meanwhile, the humidity of Dong stilt dwelling can reach a satisfactory level within 24 h except for the morning period. The satisfaction of the acoustic environment needs to be improved via reasonable structural maintenance.

Keywords: comprehensive assessment; historic stilt building; minority traditional dwellings; energy saving potentials; environmental suitability

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1. Introduction

Traditional dwellings are the treasures of human culture and witness to civilization. Their perfect climate adaptability and human comfort have highly inspired modern architecture design. Influenced by mountainous terrain, subtropical climate, and regional context, these stilt houses are widely distributed in minority areas of Guangxi, Yunnan province, and other countries in Southeast Asia and tropical islands, such as Malaysia, Laos, Thailand, Guam, Hawaii, etc. [1]. These traditional dwellings in some way also influenced the modern dwellings. Figure 1 shows the typical traditional stilted house and modern stilted dwelling of Chamorro, the aboriginal of Guam. From that, we can find their similar structural characteristics with bottom floor overheads, sloping roofs, and lightweight maintenance structures, but with different façades and spaces.

Living comfort is deeply related to the indoor environment, which not only includes thermal comfort, but air quality, acoustics, natural lighting, behavior, and contexts [2]. Current research increased the complexity level of building evaluation and analysis methods [3]. All these evaluation factors are accompanied by human thermal comfort, mental and physical health, safety, and building energy consumption. Francesco et al. put forward that the most relevant environmental factors are: thermal environment (TH), air quality (AQ), acoustics (AC), and natural lighting (LT). For dwellings, the weighting schemes can be summarized as follow: AC = 0.29, TH = 0.28, AQ = 0.22, LT = 0.21 for dwellings [4]. As for the relation between perception and behavior, few studies can be found. Some behavioral studies showed that physical quantities are related to perceptual domains; however, personal and contextual factors can also affect occupants' perception and vice versa [5–7]. The traditional dry fence-style houses in Dong villages are fully adapted to local climate and topography characteristics. The buildings are made of local materials and are mainly made of wood. The bottom of the building is overhead. According to the height of the terrain, the height of the columns reaching the ground varies, which minimizes the excavation of the base and allows for a simple ecological architectural concept. With the increased use of modern materials, most of the dwellings in Dong villages adopt flat glass windows, which effectively addresses the residential ventilation problem. The top floor is the living space for families, which means a larger space is available for this purpose; it has good ventilation and a wide view of the external landscape.

Figure 1. Traditional and modern stilted dwelling of Chamorro, Guam.

With the spread of global development, these traditional dwellings are disappearing fast and are being replaced by modern concrete buildings, resulting in a huge amount of energy exhausting and environmental problems. Restudying these traditional dwellings and rethinking the interaction of dwellings and human comfort, some hints of healthy living and energy efficiency are inspired. On-site monitoring and the field questionnaire are used to evaluate these stilted buildings comprehensively in order to take on this challenge.

Regarding research on stilt houses, some studies [8–10] have reported the building features of stilt dwelling houses in terms of site, building shape, and structural and construction technology. Some researchers focus on the relationship between the traditional dwelling building space and culture, tradition, and materials [11–13]. Assessments of traditional dwelling houses are mainly related to thermal comfort in summer and winter [14]; however, few studies exist on the on-site monitoring of the envelopment of temperature, humidity, acoustics, natural lighting, and indoor pollutants concentration, as well as other environmental variables. From the literature review and actual investigation, many people living in such dwellings are low-income groups, and most of them are in remote mountainous areas in developing countries; the living environment in some way is poor with inferior sanitary conditions [15]. A questionnaire survey was answered by the residents of the monitored house to master and evaluate their real living conditions. In general, the entire residential building fully embodies the residents' life philosophy with dynamic and static partitions and the separation of clean water and sewage [16]. Owning to its simple form, clear structure, and unique style, Dong village stilt residences in northern Guangxi are one of the most typical types of dry fence architecture in China [17–19].

The objective in this study incorporates two parts: in the first one, the traditional Dong stilt house will be evaluated comprehensively on thermal comfort, air quality, acoustics, and natural lighting by on-site monitoring; in the second, comparisons of the assessment on traditional stilt dwelling with the real-time questionnaire will be made. Meanwhile, we will discuss the potential reasons for the difference and the relationship between physical quantities and personal perception. Based on the analyses above, benefits, drawbacks, and improvements for Dong traditional houses will be put forward. It should be noted that new concrete buildings with traditional façades will be excluded.

2. Research Methods

2.1. Physical and Environmental On-Site Monitoring

The adaptability of traditional dwellings to the environment using a passive design strategy, as well as the actual temperature acceptance range of traditional wooden column dwellings, were studied in terms of thermal comfort [20]. For this purpose, the temperature, humidity, wind speed, wind direction, and $PM_{2.5}$ and CO_2 concentrations of typical Dong village traditional houses were measured. The monitoring instruments included a black-bulb thermometer, an online temperature and humidity monitor, a hand-held anemometer, and a pollutant concentration for $PM_{2.5}$ and CO_2. The instrument parameters are listed in Table 1. According to the ASHRAE measurement data, the distance from the solar radiation to the external wall is greater than 0.6 m. In this study, the monitoring instruments were approximately 1 m away from the external wall and 1.1 m away from the ground to ensure the accuracy of the average air temperature, wind speed, and humidity data by considering the height of the bottom of windows.

Table 1. Monitoring instrument specifications.

Test Parameter	Test Instrument	Model Number	Test Range	Instrument Precision	Sampling Type/min
Air dry bulb temperature	AZ temperature recorder	AZ8829	−40 °C~85 °C	±0.6 °C	Automatic record/10
Air Relative Humidity	AZ Humidity recorder	AZ8829	0% RH~100% RH	±3% RH	Automatic record/10
black-bulb Temperature	Black-bulb thermometer	JTR04	5 °C~120 °C	±0.5 °C	Automatic record/10
Wind speed	hot-wire anemometer	ST-730S	0 m/s~40 m/s	±(0.03 m/s +3% measured value)	Hand movement (HM)/60
Wind direction	wind vane	—	—	—	Hand movement (HM)/60
Surface temperature	Hand-held infrared thermometer	—	−40 °C~85 °C	0~100 °C ± 2 °C	Hand movement (HM)/60

Five monitoring points were used located at the entrance corridor, fire pool, bedroom, storage room, and bedroom on the loft floor (Figures 2 and 3). The instruments can continuously monitor the indoor environmental variables (i.e., temperature, humidity, black-bulb temperature, pollutant concentration, wind speed, and wind direction) in each space for 24 h in one week.

2.2. Questionnaire Survey and Participants

In this study, the Questionnaire Star software was used for the questionnaire survey. The questionnaire survey was divided into two parts to make the research more universal and more effective for studying the adaptability of traditional residential spaces to modern life and their thermal comfort satisfaction: the degree of satisfaction in traditional space utilization and the satisfaction in terms of thermal comfort, natural ventilation, natural lighting, sound insulation performance, indoor air quality, and other factors of the living space [21]. There are two main forms of Dong village dwellings in the survey: traditional stilt buildings with the ground floor overhead and semi-column buildings with the front building and the background. A total of 472 questionnaires were distributed (see Supplementary Materials), of which 469 were valid after three were determined as invalid.

Among the valid questionnaires, 209 were taken by male participants, and 260 were taken by female participants. The age distribution of the interviewees is summarized in Figure 4. The questionnaire survey was conducted in groups to meet the requirements of the PMV evaluation index and ensure the accuracy of the experimental data. In the questionnaire, basic information, such as clothing status, activity status, the degree to which doors and windows were opened, and the use of air conditioning equipment, was recorded. The respondents were allowed to adjust their clothes, the state of doors and windows, and the use of air conditioning according to the ambient temperature. Therefore, the questionnaire provides real-time data [22].

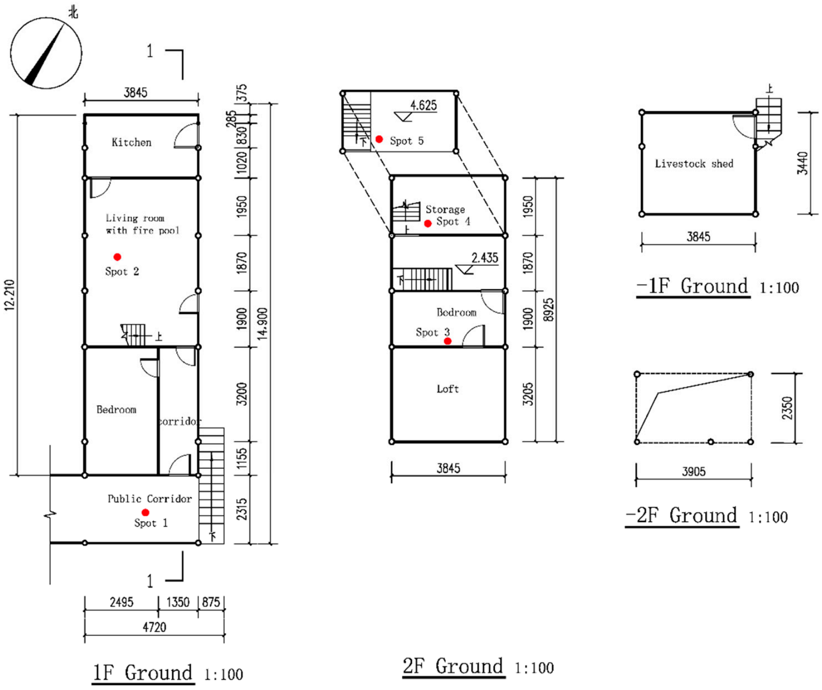

Figure 2. The layout of Dong Village dwelling with five monitoring points.

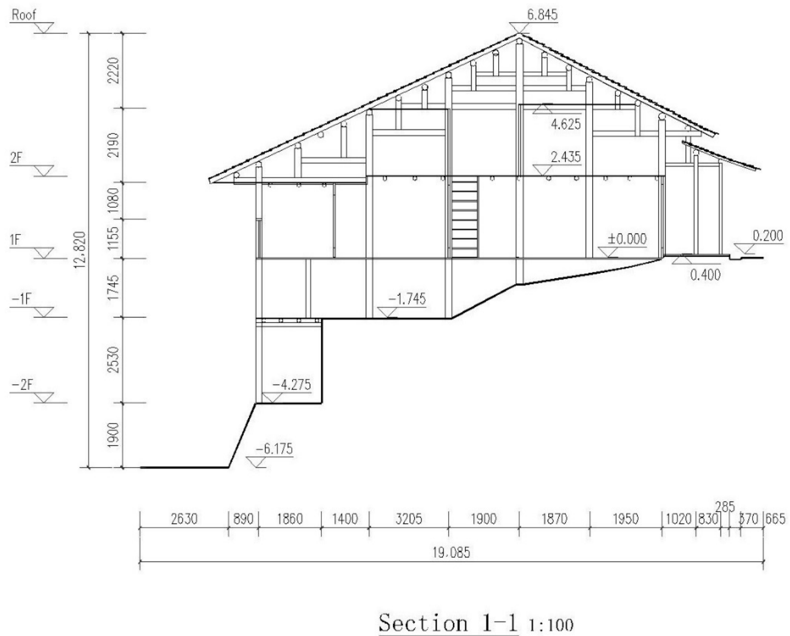

Figure 3. The section of traditional Dong village stilt dwelling.

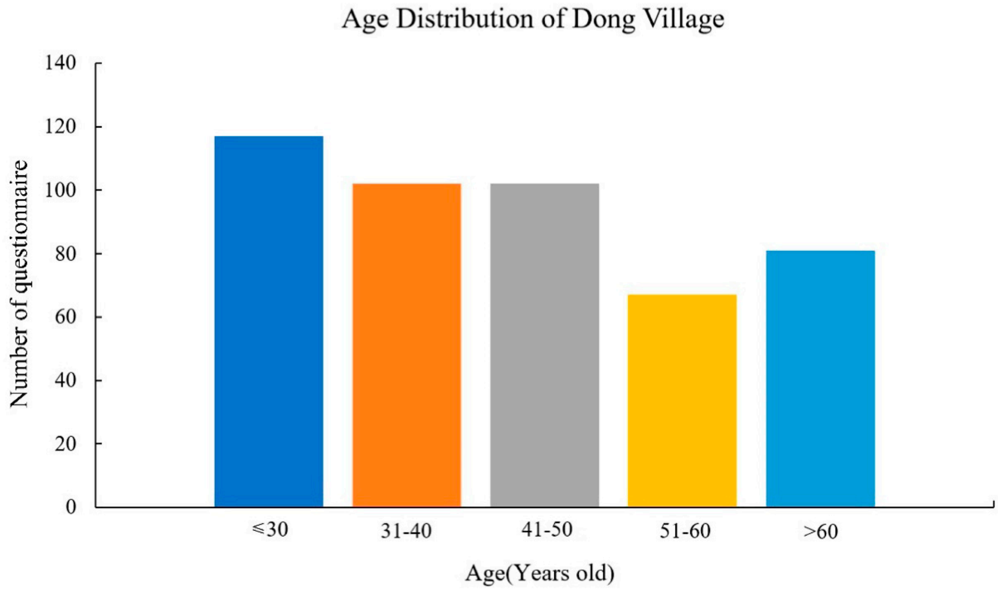

Figure 4. Age Distribution of Dong Village.

2.3. *Definition of Relevant Parameters*

2.3.1. Determination of the Dressing State and Metabolic Rate

During the questionnaire survey, all the interviewees were seated in a relaxed state. According to Appendix B of Evaluation Standard for Indoor Thermal and Humid Environment of Civil Buildings (GB/T50785-2012) [23], the average metabolic rate was set to 1.0 MET. The dressing status of residents, which is their daily outfit, is listed in Table 2.

Table 2. Dress state of residents.

Option	Subtotal	Proportion
Long-sleeved T-shirt	17	3.6%
Short-sleeved T-shirt	335	70.97%
Long-sleeved shirt	18	3.81%
Short-sleeved shirt	42	8.9%
Suit pants	49	10.38%
Jean	52	11.02%
Pants	259	54.87%
Slim skirt	38	8.05%
Dress	53	11.23%
Anklet	14	2.97%
Stocking	7	1.48%
Leather shoes/sports shoes	56	11.86%
Sandal/slipper	337	71.4%
Invalid	5	1.06%
Valid questionnaires	467	

2.3.2. Determination of Building Outer Boundary Parameters

The traditional stilt residential buildings in Dong villages are wooden structures with the ground floor overhead. Therefore, the heat absorption coefficient of one floor is considered according to the floor rather than the ground (i.e., a semi-infinite flat wall). The exterior walls of the building are generally made of a light wood partition board, which is composed of a single type of wood with uniform thermal conductivity. The roof is a sloping roof with double-tile ventilation (as shown in Figure 5).

Figure 5. Wooden exterior wall and Double-tile roof.

2.3.3. Indoor Energy Load

The questionnaire survey was conducted in August, the hottest month of the year. The average outdoor air temperature was 29.8 °C. When investigating the degree of satisfaction in terms of residential thermal comfort, the house was in a state of natural ventilation. A total of 411 respondents said that they commonly used an electric fan as the refrigeration equipment in the room, which accounts for 87.08% of the responses. In winter, they primarily relied on the fire pool for heating; however, 12 respondents said that they used electric heating and other electrical auxiliary equipment for heating. In addition, 118 respondents said they used auxiliary air conditioning and heating, but the switching frequency was low.

2.4. Thermal Comfort Evaluation Method

2.4.1. Thermal Comfort Evaluation of PMV-PPD and aPMV

Based on ASHRAE 55-2017, the effective temperature value is usually operated at a constant threshold to achieve thermal comfort under natural ventilation [24]. However, the actual thermal acceptability in traditional dwellings is wider than the standard value. What is the actual threshold of 80% thermal satisfaction for Dong village stilt dwelling? What are the critical influencing factors of the living environment? A PMV-PPD method and a field investigation were promoted to evaluate the stilted houses roundly.

ASHRAE defines thermal comfort as the thermal environment in which people feel satisfied psychologically. Thermal comfort is a subjective feeling of the thermal environment, which belongs to the broad category of physical environment, physiology, psychology, and sociology [25]. In addition, it includes four indoor climate factors: air temperature, air humidity, air speed, and average radiation temperature.

Additionally, it includes two human factors: clothing and metabolic rate. Accordingly, the PMV is expressed as follows [26,27]:

$$\mathrm{PMV} = [0.303\exp(-0.036\mathrm{M}) + 0.0275] \times \mathrm{TL} \quad (1)$$

where TL represents the thermal load on the human body. The difference between the heat produced by the human body and the heat that must be released to the external environment in order to maintain the human body's comfort reflects the thermal deviation of the human body from heat balance [28]. The metabolic rate of the human body (i.e., the rate of energy release in the chemical reaction of food decomposition) is represented by M (W/m^2), W (W/m^2) refers to the work rate of the human body (i.e., the mechanical efficiency of human body output under different activity intensities; generally = 0), Pa (kPa) is the vapor pressure, t_a (°C) is the ambient air temperature surrounding the human body and t_r (°C) is the average radiation temperature of the surrounding environment.

The actual value of the thermal sensation vote is a typical thermal comfort evaluation index, and the PMV average thermal sensation index is more suitable for indoor artificial thermal environments [29]. Adaptive adjustment is not considered in the PMV model, which leads to a deviation between the predicted average vote of thermal sensation and the actual situation [30,31]. The adaptive PMV (aPMV) in the China Indoor Thermal Environment Assessment Standard (GB/T50785-2012) was used to evaluate the indoor thermal environment to reflect the average thermal sensation index more accurately [32]. Because most of the residents in Dong Village adopt natural ventilation to adapt to the hot and humid climate during the summer, the evaluation index of non-artificial cold and heat sources in buildings was selected. The aPMV is expressed as

$$\mathrm{aPMV} = \mathrm{PMV}/(1 + \lambda \mathrm{PMV}), \quad (2)$$

where λ is the adaptive coefficient. When PMV ≥ 0, $\lambda = 0.21$; when PMV ≤ 0, $\lambda = -0.49$.

2.4.2. Thermal Sensation and Operating Temperature

The operating temperature t_{op} reflects the influence of t_a and t_r on human thermal sensation. The average radiation temperature is approximately equal to the black-bulb temperature [33]. Moreover, t_{op} is often used as an evaluation index to describe the indoor thermal environment, and it is expressed as follows:

$$t_{op} = (t_a + t_r)/2, \quad (3)$$

3. Case Study

3.1. Village Description and Space Characteristic

Dong minority village is located in Sanjiang Dong Autonomous County at 108°53′–109°52′ E and 25°22′–26°2′ N. (Liuzhou, Guangxi, China) with its history of more than two thousand years. It belongs to the subtropical humid climate zone and the thermal zone characterized by hot summers and cold winters [34]. There are four distinct seasons throughout the year, with an average annual temperature of 17–19 °C. The coldest month is January, with an average temperature of 7.1 °C; the hottest months are from July to August, with an average temperature of 27 °C. Therefore, moisture resistance, ventilation, and heat insulation are the requirements for the environmental suitability of traditional dwellings in this area. The terrain here is almost mountainous. All dwellings are built with a high adaptation of local landforms (Figure 6). In such a village, a high wooden drum tower is usually located in the center of the village, which is the center of public activities, such as meetings, ceremonies, assemblies, and entertainment. Most traditional dwellings here are wooden. In the past 20 years, residents have begun to build their houses with concrete but still decorate with traditional patterns to keep the local façade consistent, leaving their former houses decayed. However, some of them have been built for more than one hundred years. To protect such historical buildings, an overall evaluation of Dong village houses is indispensable. However, to measure all of these traditional wooden houses will require huge, unnecessary work since over 50% of the dwellings are of poor quality, and some even collapsed.

The traditional residence selected is more than one hundred years old, with a total area of approximately 107 m^2, three stories, and the ground floor is overhead (raised above the ground by stilts).

The ground floor of the building is typically used for livestock, and the upper floor is used for living and family activities. Generally, the fire pool is the center of the building plan, as shown in Figure 2. Alternatively, the fire pool is set on the first floor and is used for living activities; in this case, the top floor is used for the sleeping quarters. The entrance is generally located on the mountain's surface and has an open front porch, which is mainly used as a semi-outdoor space for drying clothes, resting, and socializing. It also serves as a banquet area for guests. It is equivalent to the balcony in modern residences. The first floor is the large main space and is generally a family communication space. The section of the building displaying the main space of a Dong dwelling is shown in Figure 3. Influenced by Dong culture, the family activity space and sacrificial space revolve around the fire pool [35]. Affected by topography, building materials, and construction expertise, the total surface area of each floor is relatively small. After the gallery and fire pool are arranged, the remaining space on the first floor is used for the kitchen and storage. The maintenance structure facing the gallery is generally a light partition, which is easily removed in summer for better ventilation. In winter, partitions are installed for wind protection and thermal insulation [36].

Figure 6. The mountainous terrain of the village.

3.2. Indoor and Outdoor Thermal Environment

The outdoor thermal environment is the main factor affecting indoor thermal comfort. The average outdoor air temperature was 27.4 °C with an average outdoor temperature range of 26.1–33.8 °C. The variation trend of indoor temperatures at monitoring Points 1, 2, 3, 4, and 5 and the outdoor temperature are shown in Figure 7 (legend 1 means point 1, and so forth). The maximum and minimum values of Point 1 are 34.1 and 25.6 °C, respectively. The corresponding values for Points 2, 3, 4, and 5 are 30.9 and 26.1 °C, 33.9 and 26.2 °C, 32.5 and 25.6 °C, and 39.8 and 25.6 °C, respectively.

Through direct solar radiation and air convective heat transfer, the heat of the exterior wall is transmitted to the interior through the walls, particularly the east and west walls, such as Point 5 with a high temperature of 39.8 °C, causing an indoor air temperature change, which can directly affect the indoor thermal comfort. Therefore, to test the thermal inertia and thermal conductivity of the maintenance structure, the temperatures of the outer and inner surfaces of the outer wall were monitored on the east, south, west, and north walls. Figure 8 shows the temperature fluctuations of the external wall facing each direction.

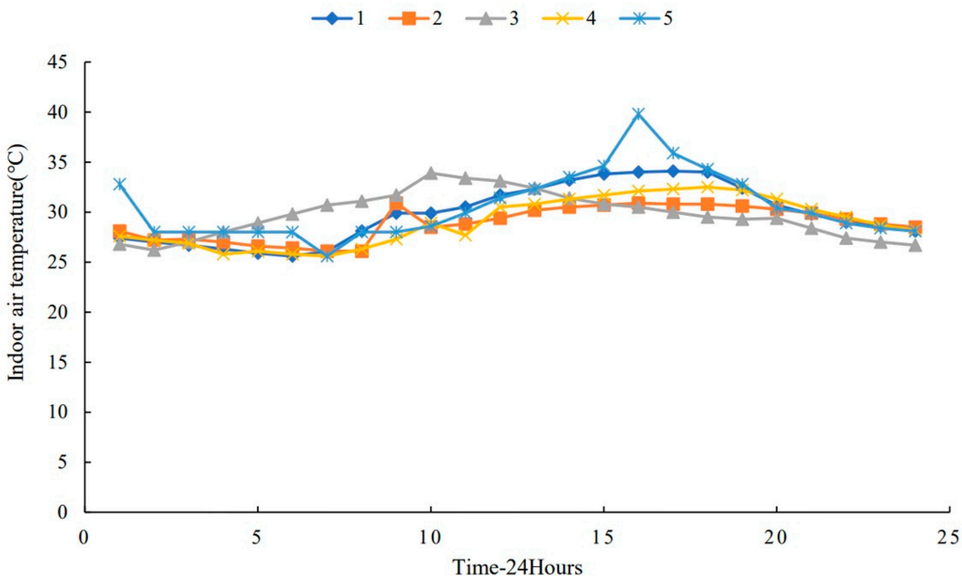

Figure 7. Variation of Indoor air temperature of 5 spots.

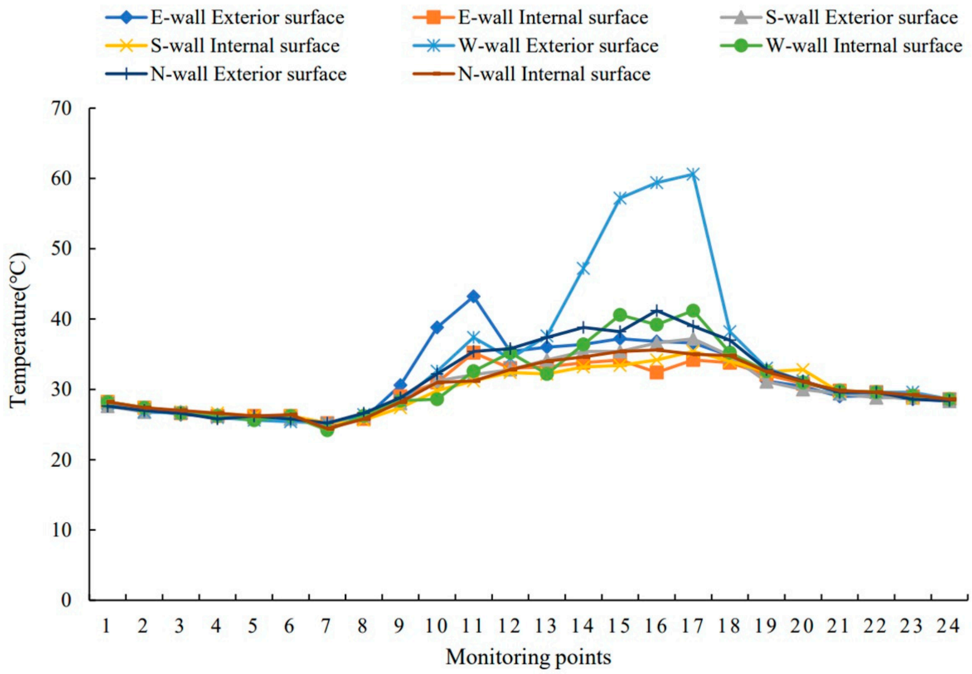

Figure 8. Comparison of air mean temperature of four external walls.

Meanwhile, Figure 9 shows the humidity changes at each monitoring point within a 24 h period. The peak humidity at Point 1 was 86.1%, the lowest humidity was 53.9%, and the average humidity was 72.5%. The peak, minimum, and average humidity at Points 2, 3, 4, and 5 were 84.9%, 67.7%, and 76.6%, 83.3%, 60.6%, and 74.9%, 87.5%, 66.9%, and 77.9%, and 85.5%, 46.8%, and 71.3%, respectively. The peak humidity occurred at 7:00 AM in all points, except at Point 1 (6:00 AM) and Point 3 (2:00 AM).

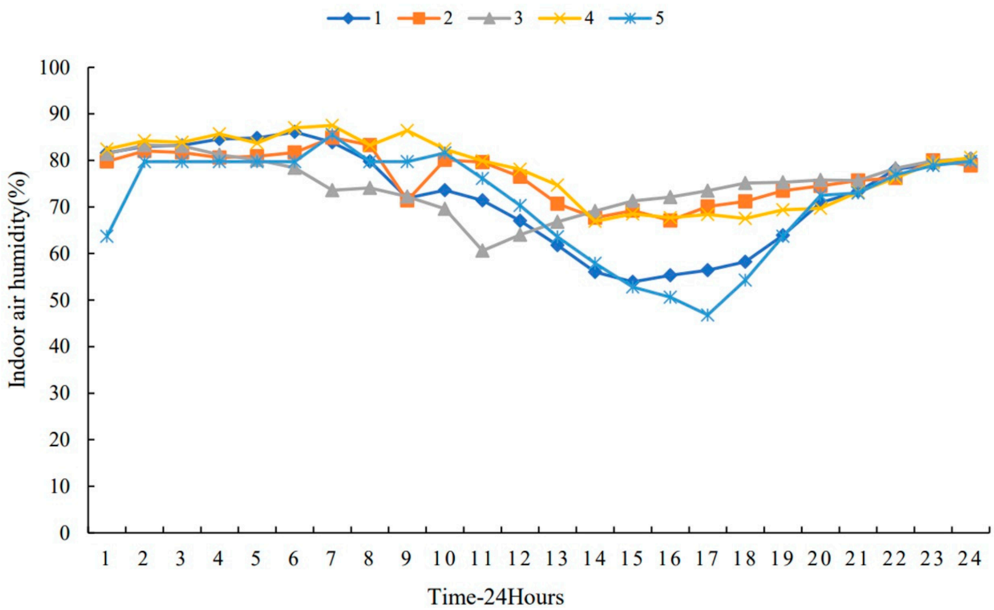

Figure 9. Indoor air humidity of five spots within 24 h.

The subjective evaluation of thermal comfort is affected by solar radiation, effective air temperature, wind speed, the metabolic rate of the human body, and clothing status. In Figure 7, it can be observed that the room temperature in summer was 25–31 °C. The questionnaire was conducted between 9:00 AM and 5:00 PM. From the answers (see Figure 10), we can know, most of the time, the aPMV in the indoor environment was 1–1.5, accounting for 42.6% of the responses. Part of the time, the aPMV was 0.5–1, accounting for 29.5% of the responses. The proportion of responses for which the aPMV was between −0.5–0.5 (i.e., in the thermal equilibrium state) was 7.2%. According to the actual questionnaire survey, the percentage of residents' satisfaction with thermal comfort is 79.3% in summer.

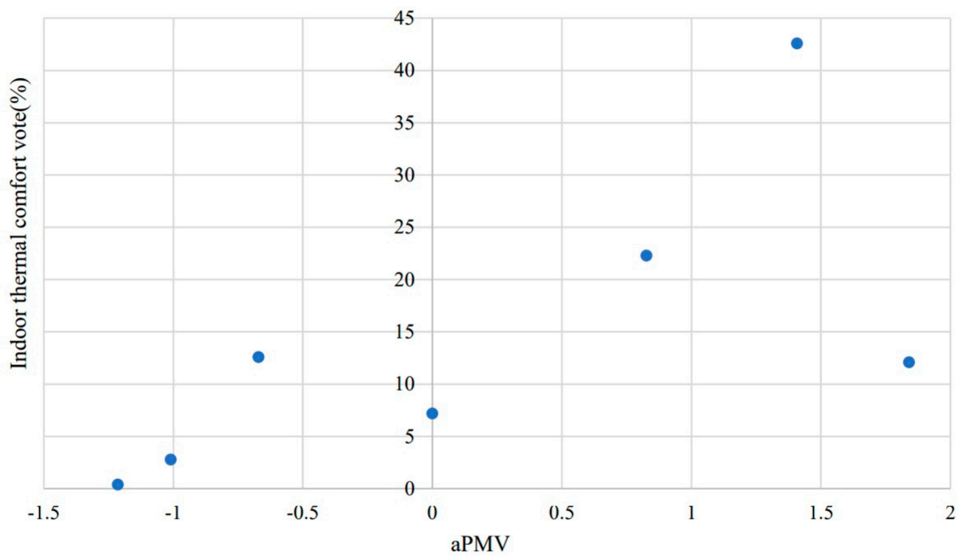

Figure 10. Distribution of indoor thermal vote.

3.3. *Satisfaction of Building Natural Lighting, Acoustic, and Ventilation*

Previously, architectural research on traditional dwellings focused on architectural space, architectural decoration, thermal comfort, energy performance, and other aspects [37–39]. Few studies are concerned with comprehensive assessment factors, including thermal comfort, living environment, occupants' behavior, or perception of traditional buildings. To fill up this gap, the natural lighting, acoustic, optical, and air quality of Dong village's traditional dwellings were investigated, monitored, and analyzed. At the same time, the behavior and sensation of residents were surveyed. To make the data and evaluation more objective, all 472 respondents we selected also live in traditional wooden dwellings, whose material, space patterns, and orientations are similar; concrete houses are not included. Referring to the thermal comfort evaluation standard, 0 is neutral, 1 is very satisfied, 2 is relatively satisfied, 3 is generally satisfied, −1 is relatively dissatisfied, −2 is not satisfied, and −3 is very dissatisfied. Table 3 shows Q21 about the overall satisfaction degree of the acoustic, natural lighting, thermal environment, and air quality of their stilt houses.

Table 3. The overall satisfaction degree of thermal, air quality, daylight, acoustic environment (Q21).

Q21. Considering the Heat, Air Quality, Daylight, Acoustic Environment, Your Overall Satisfaction with the Current Indoor Environment is ()		
Satisfaction Degree	**Number**	**Percentage**
−3 (very dissatisfied)	0	0%
−2 (not satisfied)	7	1.48%
−1 (relatively dissatisfied)	27	5.72%
0 (neutral)	35	7.42%
1 (very satisfied)	140	29.66%
2 (relatively satisfied)	188	39.83%
3 (generally satisfied)	72	15.25%
invalid	3	0.64%
Valid	469	

From the questionnaire, the acoustic survey results are shown in Figure 11 (among which five questionnaires were invalid and 467 were valid). These results show that approximately 31% of the residents are in the state of value 2 (relatively satisfied), accounting for the highest proportion among all possible responses. In addition, 18% and 19% of the residents expressed satisfaction and general satisfaction, respectively, accounting for 68% of the overall satisfaction, which means that the residents are relatively satisfied with the acoustic environment of the living space.

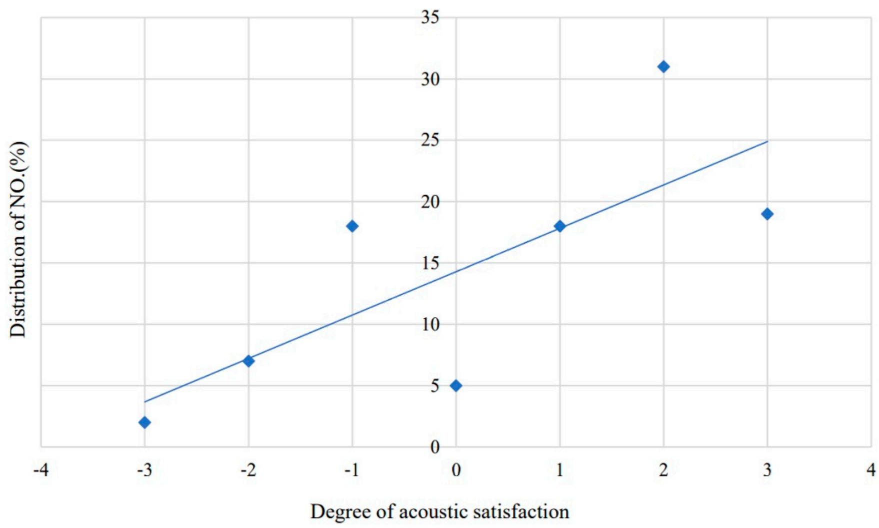

Figure 11. Distribution of Acoustic environment satisfaction.

Dong village dwellings generally have windows in the north–south direction, and the windows are small. According to the results shown in Figure 12, approximately 11% of the residents were very satisfied with the ventilation of their houses, 40% (the highest proportion) were relatively satisfied with the ventilation of the house, and 1% and 2% of the residents were very dissatisfied and dissatisfied, respectively, with the ventilation of the house. Compared with the data, the ventilation of traditional Dong village's dwellings is determined to be of general satisfaction, which is consistent with the actual monitoring results.

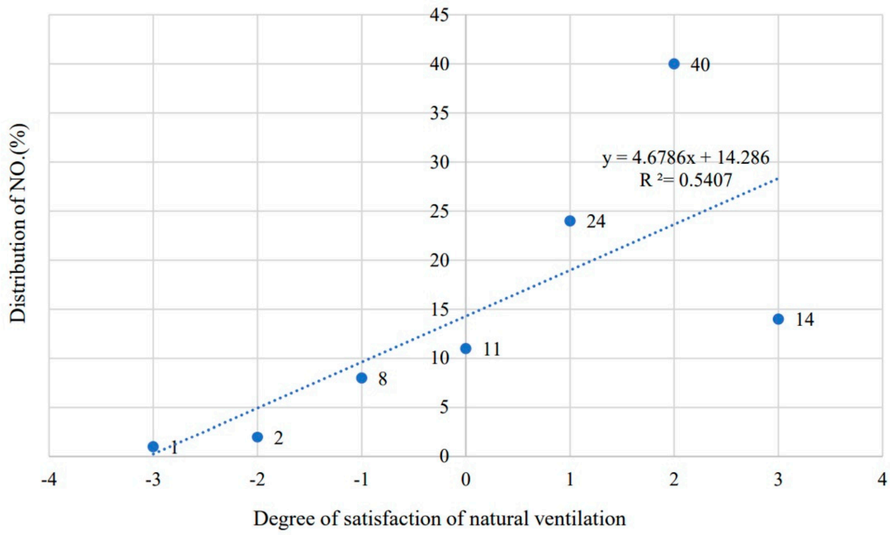

Figure 12. Distribution of natural ventilation satisfaction.

According to Figure 13, the periods of high CO_2 concentrations occur between 2–10 AM and 9 PM–12 AM, and $PM_{2.5}$ is mainly concentrated between 10 AM–12 PM and 8–9 PM. The main reason for these pollutant concentration results is that the fire pool generally used by local residents is open, and the dwellings only have small openings on the north and south doors and windows. The kitchen generally does not have windows or has small windows, with poor smoke exhaust facilities, resulting in indoor smoke that cannot be rapidly discharged outdoors.

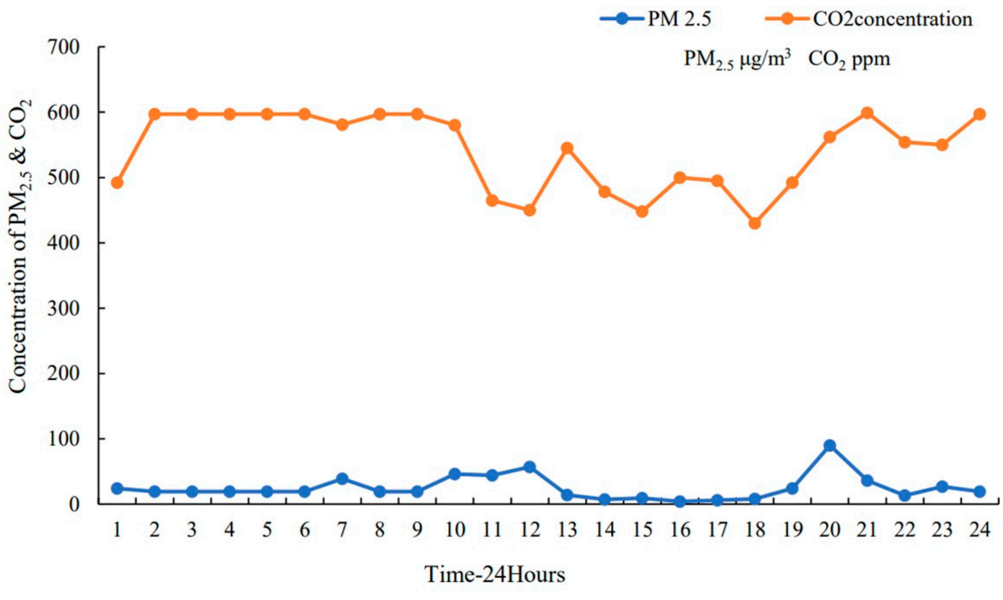

Figure 13. Concentrations of interior $PM_{2.5}$ and CO_2.

When considering the environmental factors surveyed above, every factor has a relationship with each other; for instance, air quality (AQ) is impacted by ventilation. However, the very satisfaction of ventilation only accounts for 24%, while the thermal comfort has a relationship with ventilation for residents of Dong village, ventilation is most critical, then thermal comfort, air quality, daylighting, and acoustic. For building improvement, ventilation should be considered first. However, the weighting of all factors in this study is not calculated yet; this will be our future work.

4. Results and Discussion

4.1. Dynamic Thermal Comfort Ranges of Stilt House

From the investigation and monitoring data analyzed, the thermal comfort range in traditional stilt houses is wider than urban residents. ASHRAE-55 suggested the comfort temperature for humans in the summer range from 22 to 24 °C; however, the actual comfort temperature in Dong stilt houses is from 22 to 34 °C with 79.3% aPMV thermal satisfaction. Local climate, culture, and behaviors are the potential factors of a wider thermal comfort temperature range. Moreover, reasonable building design is also critical for thermal satisfaction. The natural daytime and nighttime ventilation habit and effectiveness are helpful for thermal acceptability.

Traditional Dong village stilt dwellings generally use single-layer wooden boards as horizontal maintenance structures, and the south side is generally set with a veranda; the width of the veranda is generally 2–2.5 m. On the one hand, this design can be used as a semi-outdoor space for family activities and gatherings. On the other hand, it can be used as a sunshade component to effectively block horizontal solar radiation [40].

4.2. Analysis of Indoor Environment for Living Sustainability

From the monitoring results, it can be concluded that the time at which the highest humidity occurs is generally between 6:00–7:00 AM, which is directly related to the regional climate of subtropical mountainous regions surrounded by rivers. A low humidity environment generally occurs between 1:00–2:00 PM. However, the overall data shows that Dong village dwellings are in a high humidity and high heat environment for an extended period of time, which far exceeds the upper limit for human comfort.

According to the test results, if no refrigeration facilities are opened in summer, the indoor temperature difference fluctuation of Point 5 is the largest, and that of Point 2 is the smallest. Combined with the natural lighting conditions at different points, the external wall of Room 5 faces west, and it is without any sunshade facilities. The solar radiation is directly incident on the wooden exterior wall resulting in a large indoor temperature difference amplitude. Point 2 is located in the middle of the house and connected by the veranda in the south, which effectively blocks the direct thermal solar radiation. In the main activity space, the indoor air temperature fluctuation and the temperature difference amplitude are small. The veranda not only effectively reduces the indoor temperature but also provides a public activity space for residents, which reflects the passive energy-saving strategy and flexible and effective design of Dong village traditional dwellings. Such a strategy is also suitable for urban residences in subtropic and tropics.

4.3. Design Improvements for Living Environment of Stilt House

The stilt houses are usually located in a high humidity area, where the humidity peaks in the morning and night. It is suggested that an air barrier or moisture-proof membrane should be added near the inner side of the outer wall to effectively reduce indoor humidity by reducing outdoor moisture from entering the room. The insulation effect of the wall is poor if the single-layer wooden board is used as the maintenance structure, particularly for west-facing walls, as the wall surface temperature can reach up to 60 °C during the summer months. This greatly affects the indoor air temperature. As a rich local building material, wood can effectively reduce carbon emissions due to material transportation [41,42]. It is suggested that the single-layer wood structure should be changed into a composite wood structure. Adding glass wool or rock wool in the middle of the material is beneficial for the thermal insulation in the summer and cold winter; thus, indoor thermal comfort can be improved.

Traditional houses mainly rely on natural ventilation to remove indoor heat. When indoor ventilation is insufficient, supplemental mechanical ventilation is provided by fans, with a small number of residents choosing air conditioning. Based on observation and data analysis, it is suggested that large windows should be placed in the south wall of the house, and a row of small high windows (approximately 25–30 cm in height and one bay in length) should be placed in the north wall to form a natural ventilation mechanism in the fire pool space. A small high window can be placed above the door, which can be opened in the summer. Even when the door and the window are closed, ventilation can be effectively formed. The kitchen should be set up by an external wall with high windows, and an air vent can also be placed on the roof, such as the indoor smoke can be rapidly discharged outdoors through hot pressing effects.

The roof is a double-layer tile slope, and the tiles are directly placed on the purlin. The double-layer structure forms an air layer, which removes heat through outdoor wind flow, reflecting the wisdom of traditional residential building design. However, during our investigation, we found that the roof tiles of several traditional dwellings were damaged or displaced, resulting in indoor water and humidity leakage. The addition of waterproof felt above purlins is suggested to reduce roof leakage caused by roof tile damage.

5. Conclusions

These traditional stilt dwellings have the innate function of adapting to local climate [43]. Passive design is a key feature used to satisfy the daily requirements of residents [44,45]. However, some traditional functional spaces cannot satisfy the needs of modern life [46,47]. Several Dong village stilt dwellings have been in a state of disrepair for an extended period of time, which leads to the aging and damage of building structures and materials. This study proposed a comprehensive assessment of the historic traditional Dong stilt house. Human thermal comfort relates to temperature, humidity, and air speed, but the state of cloth, perception, and behavior also play a key role. A framework combining on-site monitoring data like black-bulb temperature, wind speed, CO_2 and $PM_{2.5}$ concentrations with occupants' sensation feedback was set up. Significantly, if we only investigate the sensation feedback of the two residents of the measured building, the deviation of the results is hardly amended. In order to obtain accurate feedback on such stilt houses, we surveyed 472 residents who lived in similar stilt wooden dwellings by questionnaires.

Based on the results of this analysis, the following conclusions are drawn:

(1) These stilt houses are usually located under high humidity and high-temperature climates. Through the questionnaire survey of 472 residents, the proportion of aPMV values in the range −0.5–0.5 (the most comfortable state) for the indoor environment was only 7.2% and 42.6% of the responses were between 1 and 1.5 (comfortable most of the time). The data reveal that the inhabitants living in stilt houses have a wider thermal comfort range than urban residents.

(2) As most of the traditional dwellings in Dong villages are overhead or semi-overhead, natural wind flow can effectively reduce indoor temperatures. However, the windows on the outer walls are small (particularly in the south direction; there are no windows facing east or west), and the front porch prevents indoor heat from being discharged outdoors through natural ventilation. This results in an indoor air temperature that is often higher than the temperature at which the human body is uncomfortable, particularly in the afternoon. Furthermore, high indoor temperatures increase the air vapor pressure, increasing indoor humidity. The combination of these two factors is the main reason for the low thermal comfort of Dong village dwellings during the summer.

(3) For natural ventilation improvement, we suggest that larger windows be placed in the south wall of the house, with a row of small high windows in the north wall to form a natural ventilation mechanism in the fire pool space. Regarding the maintenance structure, a single-layer wood structure should be replaced with a composite wood

structure. Adding glass wool or rock wool in the middle of the material could effectively reduce indoor temperatures during the summer.

(4) Through the questionnaire survey, the residents conveyed that they were satisfied with the sound environment of traditional Dong village dwellings. As a non-directional sound insulation material, wood absorbs sound very well. However, owing to the tight connection between boards, some sound is transmitted to the room, which has a certain impact on the indoor acoustic environment. The natural lighting of traditional houses primarily depends on side windows and small skylights on the roof. According to the questionnaire survey, more than 40% of the residents were relatively satisfied with the indoor natural lighting environment, particularly in the kitchen, guest bedroom, and other secondary spaces. An appropriate increase in the window area and skylights could effectively improve indoor natural lighting; however, direct glare could also occur easily. Openings could also be placed in the gables on the east and west sides to further improve indoor natural lighting.

Supplementary Materials: We updated our original questionnaire for living environment of Dong Village dwelling houses. Please refer to https://www.mdpi.com/article/10.3390/su13179966/s1, at supplementary part.

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