

Proceeding Paper

# Environmental Aspects of Vernacular Settlement of Xinpu: A Case Study for Social Responsibility <sup>†</sup>

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**Abstract:** The architectural heritage of a remote village not only forms an important part of its local history but is also a sustainable source of knowledge. The purpose of this study is to introduce the environmental factors in the design of a traditional ancestral hall located in Xinpu Township, Hsinchu County, Taiwan. The content presented covers all scales of architecture, starting from large-scale urban design to small-scale building components. First, it presents the urban form of Xinpu. The environmental investigation is based on the nine main ancestral halls, corresponding to the local climatic conditions, the sun and shade conditions of the courtyard, and the orientation of the remaining traditional houses. Then, the architecture of traditional dwellings is introduced. Environmental studies are based on a computer analysis using Ecotect. Field studies include measurements of winter and summer air temperatures in a house, while computer analysis is conducted for sunlight and shading conditions for nine ancestral buildings. Combining Ecotect Analysis, Desktop Radiance, and WinAir4, daylight levels and airflow in the houses are simulated. The results are used to explain the university's practice of social responsibility in rural areas.

**Keywords:** traditional ancestral halls; daylight conditions; wind field; Xinpu; university social responsibility



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## 1. Introduction

For a long time, the application of computer graphics in learning architecture has been for technical training. With no clear need or purpose, students only learn how to use the technology [1]. Often, there is not a strong desire for students to complete a project when they seldom use the knowledge of computer graphics. In computer-aided design (CAD) courses, the traditional learning method needs to be changed as innovation and creativity are required nowadays, and it is required to assess the learning outcome of students from a practical perspective. Fortunately, with the advent of the university social responsibility (USR) program in recent years, there seems to be a chance.

This study aims to present an experimental process of teaching and learning in a CAD course that provides a sense of purpose to students who are involved in activities of the USR program. The town of Xinpu, with its local industrial history, is a target area for the student's architectural design. Students first learn its environment from the scale of the town and then study the reasons for its orientation from the perspective of buildings [2]. Taking the traditional ancestral hall buildings as a model, an analysis of the actual urban environment is carried out to consider wind and heat factors for an appropriate design.

## 2. General Background

In the USR program promoted by the Ministry of Education (MOE), the Xinpu area is classified as a rural area that needs investment in research and support for development. In the early nineteenth century, Xinpu had become a distribution center for the three major

economic crops of cane sugar, tea, and camphor. At that time, the commercial prosperity of Xinpu was almost as high as that of Hsinchu City. Moreover, 99.1% of its land was owned privately in Xinpu Township, which caused problems in the promotion of public construction. Thus, there are not many public facilities in the area still. The terrain of Xinpu is hilly and sloped, accounting for 76.17% of the total area. However, 23.83% of the flat area includes the urban planning area, agricultural area, and industrial area under a restriction for the development of Xinpu. The geographical situation is slightly on the fringe of economic development.

### 2.1. Topography

Xinpu Township is located on the south side of the Dianzi Lake platform with many mountains and few plains. Geographically, it is run through the river Fengshan from the east and the river Xiaoli, which converges from the northeast. The main settlements in the town are found along the river steps of the valley. The land develops to the eastern and western sides and gathers into streets in the narrow alluvial plain (Figure 1).

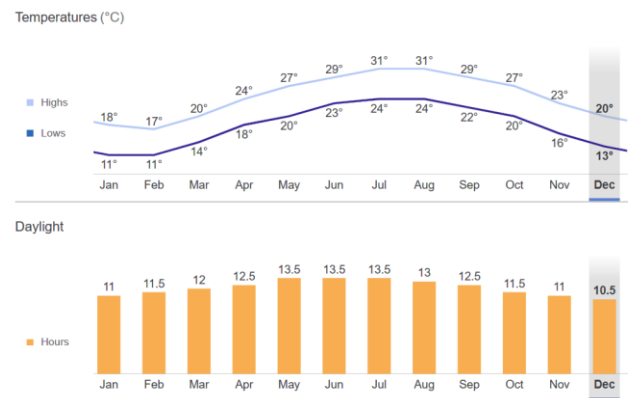


**Figure 1.** Topography of the vernacular settlement of Xinpu. Source: Google Map, <https://www.google.com.tw/maps/@24.8272863,121.0759617,1459m/data=!3m1!1e3?hl=zh-TW&entry=ttu> (accessed on 2 October 2022).

### 2.2. Climate Analysis

The climate of Xinpu has an annual rainfall of about 2322 mm. From February to September, the rainy season with more rainfall occurs, while the dry season lasts from October to January with less rainfall. The dry and wet seasons are not obvious. Although the wind continues to blow, the air is not dry, due to the high humidity. From January to April and from October to December, clouds cover the sky almost every day. The total annual evaporation is 1041 mm, which is less than the annual rainfall. Only in October is the evaporation greater than the rainfall, so there is no shortage of irrigation water.

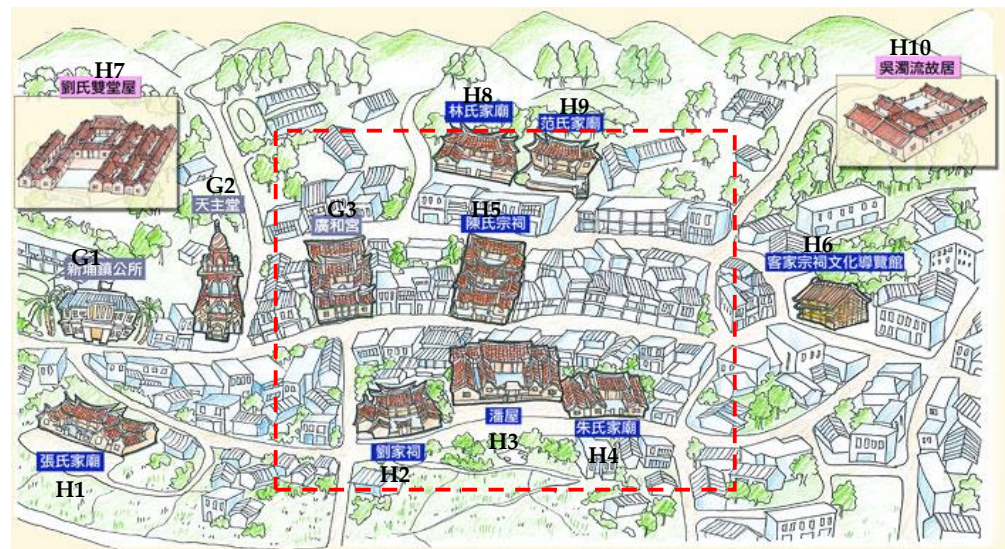
Hsinchu's monsoon index is the highest among the counties and cities in the west, so it is called "Wind City". This weather is closely related to its geographical location because Hsinchu is only 150 km away from the narrowest point of Pingtan, Fujian Province, across the Taiwan Strait. The wind speed increases at the narrowest part of the gorge, especially during the northeast monsoon season. Especially during September, the speed of the wind reaches 20 m/s. Xinpu has a subtropical oceanic climate with an annual average temperature of 21.3 °C. Higher temperatures are observed in July and August with average temperatures of 28.1 °C and 27.6 °C. The temperature is the lowest in February with an average of about 13 °C. Figure 2 shows the monthly temperatures and daylight hours.



**Figure 2.** Monthly values of temperature and daylight hours. Source: Weather and Climate, <https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,hsinchu-city-hsinchu-county-tw,Taiwan> (accessed on 5 May 2022).

### 3. Environment

Xinpu was a prosperous town for the Hakka people in the Qing Dynasty. According to the topography and the size of the population at that time, a spatial pattern of Three Streets, Six Lanes, and Nine Ancestral Halls (Figure 3) was formed [3]. Along the old streets of Xinpu today, it looks like a clan museum without walls, and traces of Hakka's efforts can be seen everywhere.



**Figure 3.** Three Streets, Six Lanes, and Nine Ancestral Halls in Xinpu. Source: Xinpu Ancestral Museum Promotion Association, <http://210.63.200.70/exhib.asp>. (accessed on 2 October 2022) (G1: Xinpu Town Office (新埔鎮公所); G2: Cathedral (天主堂); G3: Guanghe Temple (廣和宮); H1: Chang Family Hall (張氏家廟); H2: Liu Family Hall (劉家祠); H3: Peng Family Hall (潘屋); H4: Chu Family Hall (朱氏家廟); H5: Chen Family Hall (陳氏宗祠); H6: Hakka Culture Guide Hall (客家宗祠文化導覽館); H7: Liu Family Twin Hall (劉氏雙堂屋); H8: Lin Family Hall (林氏家廟); H9: Fan Family Hall (范氏家廟); H10: Wu's former residence (吳濁流故居); The red dotted line marking the location of the core testing area (shown in Figure 4)).



**Figure 4.** The location of the core building group in Figure 3. (Source: Google Map, 2022).

### 3.1. Urban Area

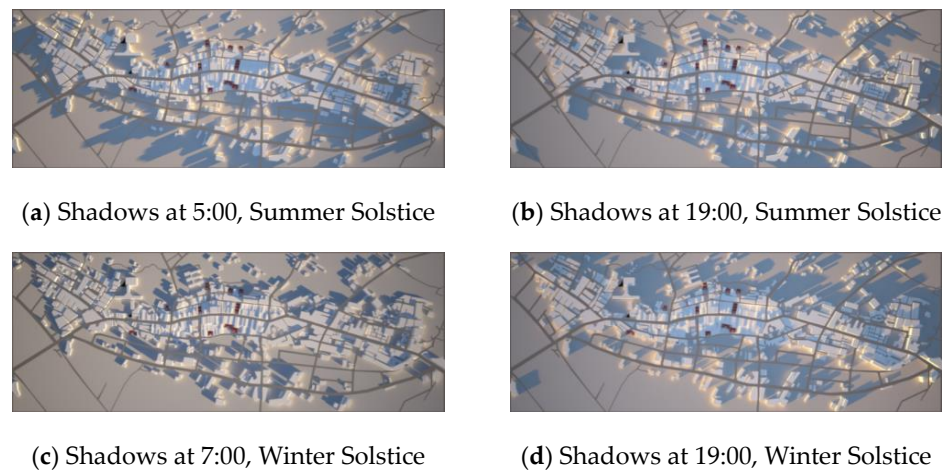
The three parallel east–west streets are the core of the life of the people of Xinpu. There are more than six small alleys intermittently, connecting the three main streets into a network in the north–south direction. There are the ancestral hall buildings of the major families, which are scattered on these three streets with the buildings facing south. Affected by the northern mountain’s shape and the direction of the stream, the three parallel streets are located close together. The streets in the middle naturally become the core commercial streets. The main street on the south side accommodates the people’s livelihood and consumption places in the town. The largest fruit and vegetable market and most restaurants are located on the south side. The north side is dominated by stores selling daily necessities, government agencies, and cultural and educational palaces and temples. On the other hand, the low-rise buildings at the foothills on the north side are dotted with small wholesale stores, all of which are mixed residential and commercial buildings.

### 3.2. Orientation and Shading Conditions of Buildings

In such a long and narrow road network, almost all buildings face the street with a south or north orientation. Except for the nine ancestral halls and the cultural and educational institutions, most of them are built in the form of shophouses. Of course, what we see today are modern, long, multi-story buildings, not traditional shophouses with several internal courtyards. Figure 4 shows the range of the red dotted line marking the location of the core building group. All family ancestral halls and temples must face south. In addition to conforming to the topography and the direction of traffic flow, it also fully complies with the requirements of traditional Chinese Fengshui.

There are two types of traditional courtyard houses in Chinese villages: closed and open. Building materials are either brick or wood, depending on local conditions. Moreover, most of the houses in Taiwan face south. In the middle of the north side, there is the main room, and on the left and right, the living room and the granary are located. The east wing is used as a kitchen and dining room, and the west wing is used as a bedroom. There are walls built to connect the east and west wing rooms, and the doors are opened at the opposite side of the wall. The main room is close to a courtyard, and rooms without walls are used as open courtyards. The open space in the middle is mainly used as a drying area, and flowers, plants, and fruit trees are planted around it. With the development of the local economy, more rural brick houses and urban buildings are under construction.

Using Ecotect software, the shading conditions of the environment of Xinpu settlements were analyzed, and a later rendering was carried out. The three-dimensional model was drawn and tested for the summer solstice (22 June) (Figure 5a,b), the winter solstice (22 December) (Figure 5c,d), and the spring/autumn equinox at representative hours of the day.

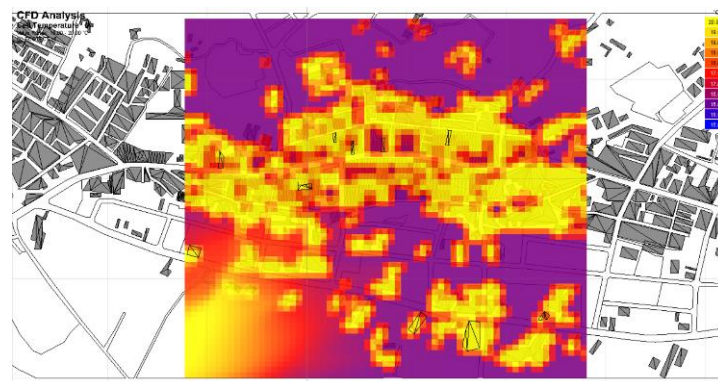


**Figure 5.** Ecotect rendering for the Old Street of Xinpu Township in the daytime. (Source: Author 2022).

Lower sun elevations in the winter shade significant portions of the atrium, while in summer, shadows are minimized. Since the vast majority of settlements are on the south-southwest side of the valley, the main direction of the housing is north to southwest. Additionally, many houses face south or north. However, the ancestral hall buildings must be oriented towards the favorable south.

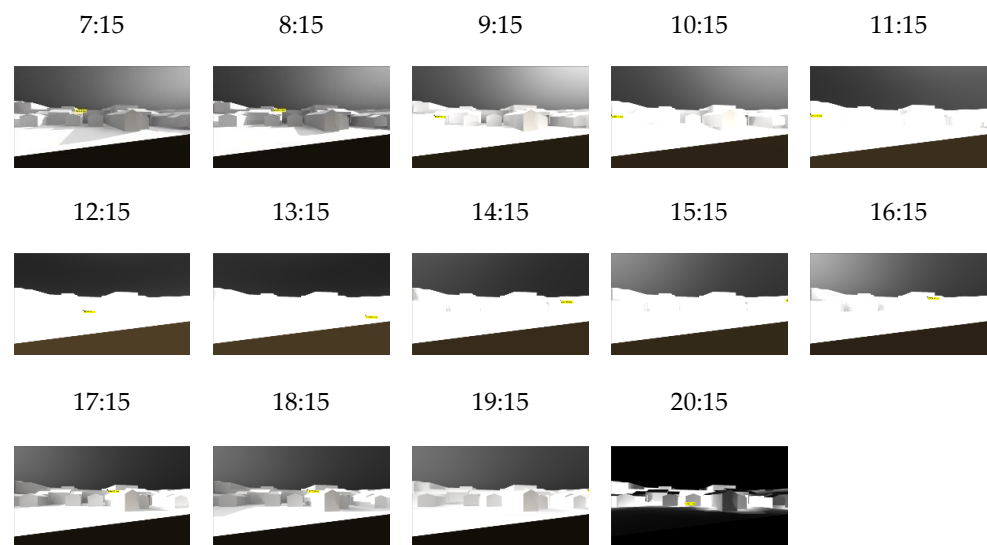
#### 4. Environmental Aspects of Daylight

On the whole, the sunshine duration in Xinpu is sufficient and even intense. The ancestral hall buildings are relatively concentrated. Figure 6 shows the distribution of the air temperature under fluid analysis. Although they are all low-rise buildings, the air temperature is relatively high due to the large and dense shophouse buildings [4]. Therefore, the combination of warmer temperatures and long hours of sunshine makes Xinpu a warmer area.

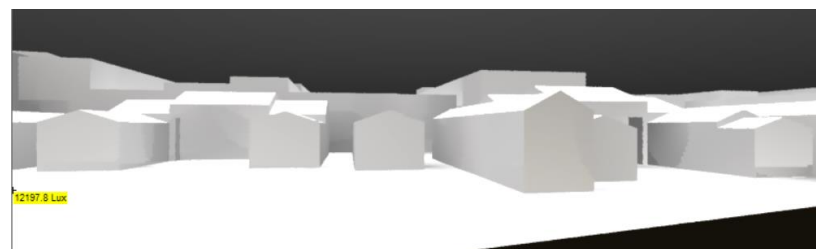


**Figure 6.** Cell temperature by CFD analysis in the area of the ancestral hall buildings. (Source: Author 2022).

The Pan Family House on the southernmost side of Old Street is shown in Figure 7. In summer, there are up to 8 h of strong sunshine from 9 am to 4 pm. The average sunlight intensity is as high as 25,000 lumens. However, it is soothing in the winter, and the average intensity is about 11,000 lumens (Figure 8). The plants on Old Street are distributed on the hillside on the north side, and the rest are scattered on the southeast side. The larger and older plants are distributed around the ancestral hall buildings.



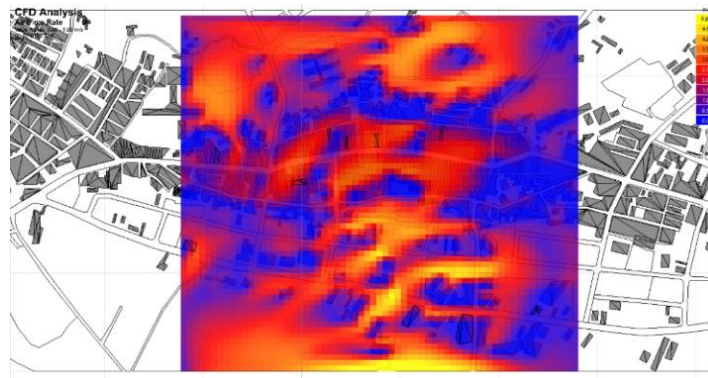
**Figure 7.** An ancestral hall (the Pan Family House) building facing south, in the sunshine of the summer solstice. (Source: Author 2022).



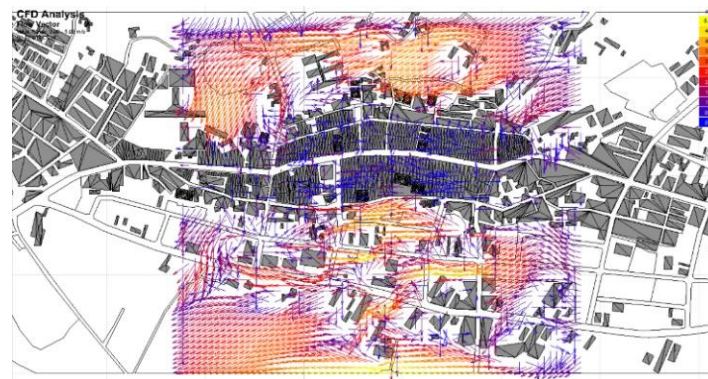
**Figure 8.** Facing south, the Pan Family House building in the sunshine of the winter solstice at 1 pm. (Source: Author 2022).

## 5. Environmental Aspects of Wind Flow

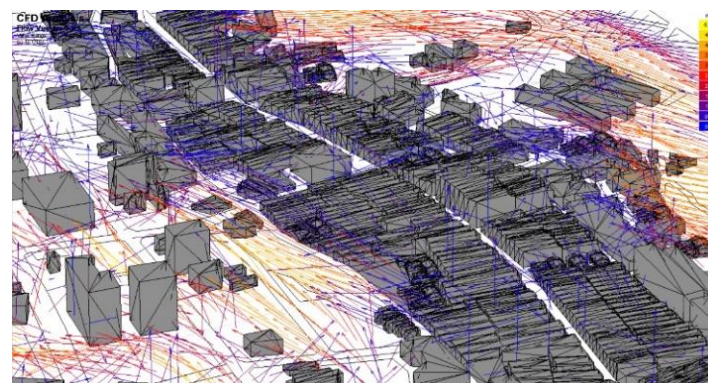
The wind flow in the town is interesting. The east–west slope on the north side blocks the famous ‘Nine-Falling Wind.’ However, the gentle slope on the south side and the open stream on the east side allow the northeast monsoon in September to blow on the old streets of Xinpu. Figures 9 and 10 show the period when the Nine-Falling Wind prevails with the change in building volume. The flow and distribution of the air change drastically and in an instant. The change in wind direction is observed from the vector diagram (Figure 11). The simulation and analysis of the wind field are carried out with Cardiff University’s WinAir4, and the visual performance is controlled with Ecotect Analysis. The disadvantage of WinAir4 is the limitation of the number of grids, and its three-dimensional proportions cannot be completely consistent. Therefore, the estimated results can only be used as a preliminary reference. However, it has the advantage of ease of use and free use for research purposes.



**Figure 9.** The airflow rate of Xinpu Old Street under the action of the Nine-Falling Wind. (Source: Author 2022).



**Figure 10.** Diagram of the Nine-Falling Wind in flow vector format. (Source: Author 2022).

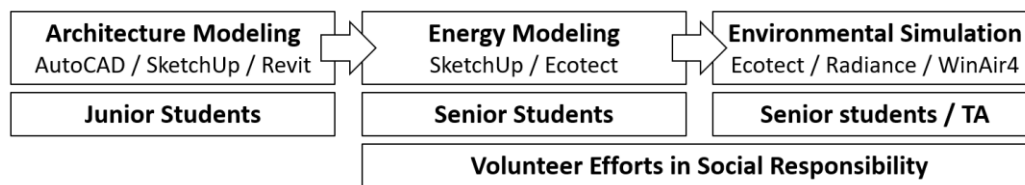


**Figure 11.** Flow vector diagram of the Nine-Falling Wind on the side of north-south. (Source: Author 2022).

## 6. Conclusions

This research project in Xinpu Township was carried out for three years. In the first year, a small space renovation plan was performed for a small corner of the town. In the second year, we conducted a preliminary analysis of pedestrian flow to obtain complete basic data for subsequent research. Xinpu has a rich cultural atmosphere. The ancestral hall buildings are scattered in the Three Streets area with a reputation as an open museum owing to their good preservation. The traditional shophouse architecture has almost been replaced by modern concrete buildings. At first glance, the whole old street area can seem like a modern town. Without this batch of traditional buildings, the significance of the research may be lost.

The USR Project is provided for student learning. Therefore, we designed a learning road map (Figure 12) based on a physical environmental analysis [5]. Software including AutoCAD 2D drafting, SketchUp 3D modeling, Revit modeling, Ecotect Analysis, Desktop Radiance, and the CFD of WinAir4 was used.



**Figure 12.** Diagram of the teaching/learning road map of the environmental aspect of the vernacular settlements. (Source: Author 2022).

In terms of the construction of basic spatial models, students can handle it freely. The analysis of the light environment involves a lot of theories. Because the models provide tangible objects, students can master the essentials of manipulation. The application of ventilation is the most difficult for students to learn. The theory is not easy to understand, and the calculation process is tedious. Even if the analytics can be calculated, they may not have the corresponding ability to explain it. In the USR Project, students learn the process of local development and problem-solving based on local-based courses and activities [6]. To guide students to learn independently and promote a cooperative mode of field practice learning and sharing among students, the integration and reproduction of knowledge need to be encouraged, which allows the development of new teaching models and research.

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