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Towards Eco-Vitality Pedestrian Street: Research on the Design of Traditional Commercial Street Oriented by Green Energy and Thermal Comfort

Meiting He^{1*} and Wenting He²

¹Phd. Candidate, College of architecture and urban planning, Tongji University, Shanghai, 200092, China

²Master's degree student, School of Architecture, South China University of Technology, Guangzhou, Guangdong, 510641, China

*Corresponding author's e-mail: hmt@tongji.edu.cn

Abstract. This paper attempts to take the thermal comfort model and the concept of green energy conservation as a new perspective to study the traditional commercial pedestrian street, trying to make the transformation of the traditional pedestrian street achieve the goal of ideal comfort, taking the traditional West Street in Jiading District of Shanghai as an example. Firstly, through cases study of traditional commercial streets in southern China, the traditional wisdom of vernacular buildings and spaces in responding to regional climate is analysed in detail. Secondly, according to the detailed information of the project, combined with the field thermal imaging survey, the performance of simplified models of different spaces is simulated by dynamic simulation tools (such as Ladybug, Honeybee and Butterfly based on Rhino-Grasshopper). The multi-objective performance simulation optimization aims at thermal comfort, wind and sunshine environment, and compares thermal comfort at different spatial levels and at different times. Considering the thermal comfort and activities of commercial streets in the research project, it is found that there will be great differences in thermal comfort performance under different space forms, and the micro-environment design will effectively improve the comfort of the area, which is conducive to creating an eco-friendly and lively street environment.

1. Introduction

1.1. Ecological deficiency of Historic Pedestrian Blocks

In China, with the continuous development of economy and the expansion of modern cities, even extending to traditional rural districts, the old traditional areas are gradually "disappearing" in development. The New Urbanism put forward in the 1990s supports the inevitability of urban growth, but the decline of the central city and the disorderly spread of the city will lead to the imbalance of urban development and will cause serious social problems [1]. Its main theories include the traditional Neighborhood Development (TND), which advocates the re-integration of the architectural environment from macro to micro, to form diverse, walkable, compact and mixed urban, city, rural and neighborhood units. Its purpose is to improve the quality of life of the whole community residents and even the whole human community [2]. Even Europe has been at the forefront of area-based conservation, and even though most historic quarters are today protected through designation as conservation areas, not all of them have had access to the necessary financial support to back rehabilitation and conservation



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programmes. Consequently, poor resident populations continue living in dilapidated buildings in a fight against ongoing decay, as in the Albaicín quarter of Granada in Spain with a strong ecological vernacular tradition [3].

However, the disappearance of historic blocks stems from a variety of problems, such as the lack of repair and management, the lack of coordination between economic activities and living environment, separation from its original value after transformation and tending to be unified and ordinary, etc.[4] Similarly, the new urbanism realizes that solving such urban problems requires not only close material structure support, but also a dynamic and development-oriented economic system, a sustainable and stable community, and a healthy green ecological environment. This paper focuses on how to build a green and dynamic historical pedestrian street, find ecological wisdom from traditional architecture and its essence, and rebuild the neighborhood environment and atmosphere adapted to local climate, human environment and user comfort.

1.2. Ecological Vitality: Environmental Adaptation and Spatial Exploration

Compared with urban buildings, traditional vernacular buildings can better reflect the impact of local climate and environment on buildings. For example, the water towns in the south of the Yangtze River have similar layout characteristics, and the centralized and dense residential buildings in the South have similar arcade space to guide the passage of the hall. Because they often pay attention to culture and other factors, but also to specific regional climate, emphasizing the shelter function of buildings for people, the traditional way of building is usually to express people's response to local climate by relying on long-term technology and crafts to deal with climate conditions. Therefore, compared with elegant buildings, vernacular architecture is considered to be more adapted to climate conditions [5].

At the same time, due to the lack of architects' participation in the construction process of local architecture [6], this self-organizing process can better reflect the relationship between human physiological and thermal sensation and architectural environment. Therefore, the study of the relationship between the environmental control strategy of vernacular architecture and human physiological and thermal comfort plays an important role in exploring the development of ecological green buildings and the protection of traditional buildings.

2. Methodology

In this paper, case study is used as the object of preliminary investigation. Through the retrospect of several historical blocks in the humid and hot areas of the south, it is believed that they have similar spatial characteristics and street forms to cope with the special southern climate environment and adapt to the local people's life and production activities. Firstly, the key words of "climate adaptability" and "commercial pedestrian street" are searched extensively, and the research literature, works, research results in relevant fields around the world are searched, and the research data are systematically collated and summarized, from which the existing problems and shortcomings of relevant research are found. The following are the research methods for the humid and hot areas in the south.

2.1. Spaces study and induction in southern China

The commercial street space adapted to the characteristics of regional eco-climate and thermal comfort needs can be subdivided into three levels: macro, meso and micro. From three aspects of spatial planning, spatial structure and space, the factors affecting the climate adaptability of commercial street are divided into three categories and eighteen major details, such as street direction, width, spacing, interface, concession distance, entrance space form, building height combination, building monomer, ventilation corridor, courtyard, arcade, balcony, etc. Selecting the relevant cases of traditional commercial street space with southern characteristics, the principles to be followed are not only to meet the needs of the times, but also to meet the inheritance of regional cultural characteristics and the advantages of ecological climate.

2.2. *Spatial Comfort Analysis of Ecological Historic Street*

At present, the research on climate adaptability and ecology in China has taken shape, but most of them are focused on theoretical research and relatively few on practical research. The research scope mainly concentrates on the macro and micro levels, while the research on the between level mainly focuses on residential district planning. The research on the area of streets and blocks is relatively deficient, especially on the comfort of historic streets.

2.2.1. Subjective Evaluation and Thermal Comfort Analysis. In the mid-1970s, in response to the oil crisis, the adaptive theory of thermal comfort was first developed. Since the 1990s, with the change of global climate and the increase of energy consumption, the adaptive methods of thermal comfort have been revived. The representative viewpoints of adaptive thermal comfort theory mainly include modified PMV model and adaptive model. Humphreys first systematically collated the data from the field study of global thermal comfort [7]. He found that people's neutral temperature is related to outdoor climate conditions. He also proposed for the first time a method of predicting neutral temperature by outdoor temperature, and established a thermal adaptation model, that is, the linear relationship between neutral temperature and outdoor temperature.

In 1998, Brager and de Dear carried out the renowned RP-884 project worldwide, and established the ASHRAE field research world database [8]. Through observing and analyzing the adaptability of 21,000 sets of data, the thermal adaptation model of neutral temperature of natural ventilation buildings with the change of average outdoor air temperature was obtained.

More and more attention has been paid to the application of adaptive model. Direct use of static thermal comfort standard based on thermal balance model as the analysis benchmark of passive climate design will bring adjustment error, which makes indoor temperature deviate from the actual thermal comfort of human body. Yang Liu used the linear regression relationship between the neutral temperature of natural ventilation room and the average temperature of outdoor as the basis for determining the thermal comfort zone in building climate design analysis maps of typical cities in China (2003, Yang Liu). The LEED green building evaluation and many energy consumption simulation software in the United States have also used thermal adaptation model as the evaluation criteria. The application of thermal adaptation has attracted more and more attention.

This paper will use Outdoor Comfort Calculator based on Rhino-grasshopper to calculate the Universal Thermal Climate Index (UTCI) of Historic Street. This is a Ladybug-based environment analysis plug-in, which is a Plugin for Environmental Analysis (GPL) started by Mostapha Roudsari.

2.2.2 Elements of Microclimate Environment in Traditional Street. For a long time, vernacular architecture is the most real reflection of local climate and environment, while climate also creates the diversity of vernacular architecture. As Frampton pointed out, at the level of deep structure, climate conditions determine culture and its way of expression, its customs and etiquette [9].

According to the climatic characteristics of Shanghai, it is hot, humid and rainy in summer, mild in spring and autumn, and cold in winter. The climate and environment are comfortable from March to May in spring and September to October in autumn. The uncomfortable periods are concentrated in June to September in summer and November to March in winter. For the outdoor pedestrian street, how to create a cool and comfortable outdoor environment in summer has a strong control over the historical blocks from the perspective of climate adaptability and is particularly important for human activities. Therefore, this paper focuses on the relatively uncomfortable climate in summer, and studies how to improve the environmental comfort of this season at the spatial level of green ecology of traditional buildings in order to create green and dynamic traditional streets.

In this paper, the site of specific investigation and analysis is selected as the West Street Block of Jiading Old Town (figure 2), Shanghai, preserving the traditional buildings with historical value. Now the old city of Jiading still has two historic preservation areas, Zhouqiao and Ximen (figure 1). The total area of the historic and cultural landscape area of Zhouqiao is 492,000 square meters. The core area includes three independent parts, namely, the Fahua Tower and Zhouqiao, Qiuxia Nursery and

Confucius Temple. The total area of Ximen historical and cultural landscape area is 453,000 square meters. It is characterized by typical folk houses and traditional commerce in the south of the Yangtze River. The pattern of street and river interdependence is obvious, and the spatial scale of streets and lanes is suitable. It is a centralized portrayal of traditional city life. West Street is the most complete preserved old street in the ancient town of Jiading. West Street is the birthplace of the ancient city of Jiading. During the reign of Tianjian in the Liang Dynasty (502 AD), the imperial court was dedicated to the construction of the Huguo Temple in the area where Jiading West Street was located. The city of Lianqi has become a city because of the Temple of Protecting the Nation. In the long history, Lianqi has been accelerating the process of urbanization. During the period of the Republic of China, West Street entered its heyday, with more than a hundred old names, and many historical celebrities appeared politically and culturally.



Figure 1. Map of Protected Areas in Jiading City.

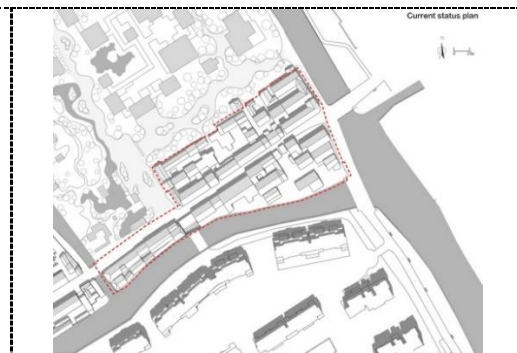


Figure 2. West Street block status plan.

Jiading District is located in the northern margin of the North Subtropical Zone, where southeast monsoon is prevalent. In hot season, it has abundant precipitation, warm and humid climate, moderate light and temperature, and abundant sunshine. According to the meteorological data of Jiading County Meteorological Station from 1959 to 1987, the annual average temperature is 15.4 °C, the annual average rainfall is 1077.6 mm, the rainy day is 130.2 days, the annual average sunshine is 2114.8 hours, the annual average total solar radiation is 114.5 kilocalories/square centimeter, and the annual average number of frost-free days is 223 days[10].

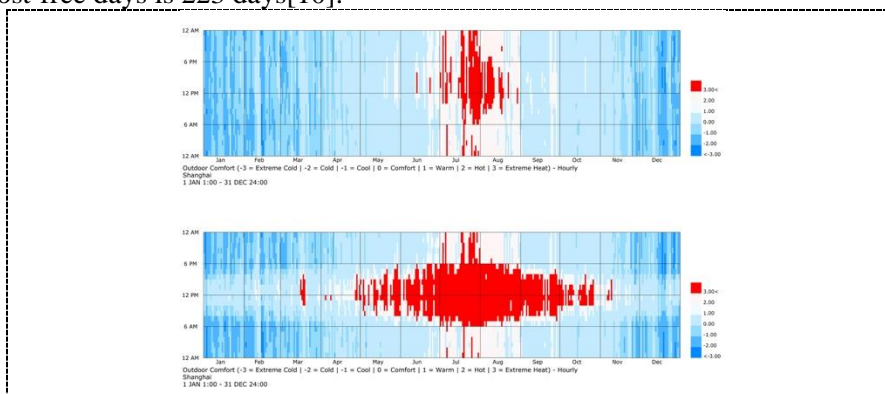


Figure 3. Comparisons of year-round comfort with and without shading.

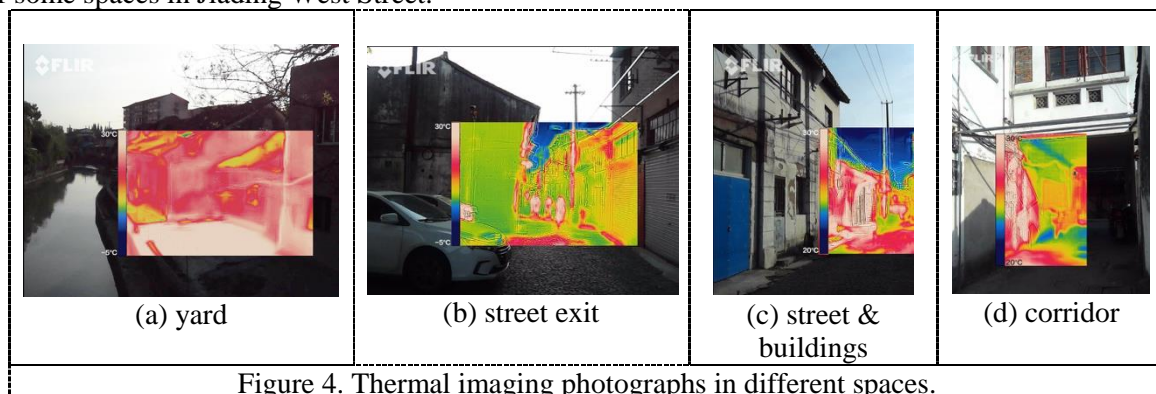
Through the analysis of climatic data throughout the year, it is found that most of the local dry bulb temperature is not within the comfort zone. In winter, warmth needs to be strengthened, while in summer, it is too hot and needs cooling and ventilation. In order to further analyze human thermal comfort, the factors considered are not only dry bulb temperature, but also humidity, wind speed, wind direction, ground reflection, human activities and clothing coverage. By adjusting MRT (average radiation temperature), the annual thermal comfort of Shanghai can be obtained. By comparing the shadows with those under the sun, it can be found that the size of solar radiation has a significant impact on thermal comfort. Direct sunshine increases the number of days that can reach the comfort zone in a year, but it

also makes some comfortable time points give people the feeling of overheating. Considering people's activities under the shadow or direct sunshine according to their needs, there is still nearly half of the year in the comfort zone, which requires proper regulation of the building environment.

2.2.3 Objective evaluation and spatial extraction. The overall trend of historic blocks is related to the choice of the orientation position of the sun. This paper attempts to use Ladybug Tools to analyze the sunshine trajectory and radiation of the target blocks throughout the year.

West Street is about 200 meters long, and the whole street has a long history and antique Tange Road. The southwest section of West Street has a wider road, about 8m. The north side is a newly built six-stored residential building, and the south side is a single-stored sloping roof commercial and residential building. The northeast section of West Street has narrow roads, with single-stored commercial and residential buildings on both sides. The 200-metre West Street is characterized by its strong traditional folk customs, the gathering of temporary vendors and a strong sense of life, but the situation along the street is more chaotic and complex, lack of management, narrow and not conducive to traffic. This paper studies and summarizes the climate-adaptable building spaces of the corresponding traditional historical blocks of West Street, such as courtyard, public space, square, corridor, and so on, and makes preliminary screening and induction for them.

In order to discover the thermal comfort difference of physical space in different historical blocks under the same climate condition, the thermal imaging measurement of specific space is studied. Any object whose temperature exceeds absolute zero gives infrared radiation. The higher the temperature, the stronger the radiation. The task of thermal imaging measurement is to transform infrared radiation into electrical signals by means of a detector and generate thermal imaging images through signal processing. Thermal imaging can help to quickly identify the surface temperature of an object in real environment and assist in comfort analysis. Once the interface temperature is too different from the air temperature, users in this space will be in an uncomfortable state. Fig. 4 is a thermal imaging analysis of some spaces in Jiading West Street.



3. Result

3.1. Building Boundary and Thermal Radiation of Traditional Street

By selecting typical street space of Jiading West Street and simplifying and abstracting the physical model, the outdoor thermal radiation and comfort were simulated and analyzed.

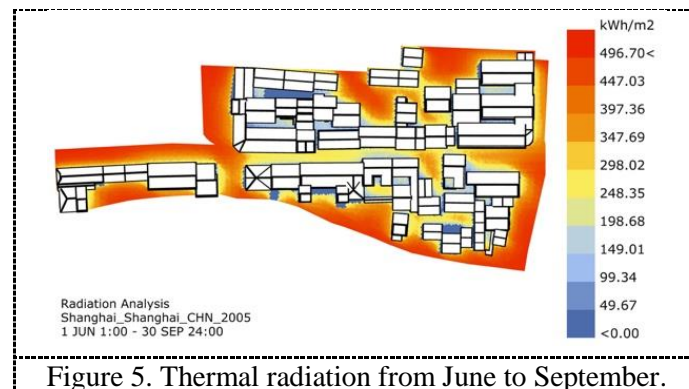


Figure 5. Thermal radiation from June to September.

Figure 5 is a solar radiation analysis of the whole street block. It can be found that during the whole year, the thermal comfort brought by the different orientation of the building envelope structure is obviously different. Most of the building forms within the block are based on the direction of the block, facing the Southeast direction, which is a kind of building layout mode conforming to the local climate. For example, the south-facing envelope of the building captures the largest amount of solar radiation in a year, which is more comfortable in winter, but it feels overheated in summer. The functions of traditional buildings are related to solar radiation acquisition in various directions, and more sunshine can be obtained by adding a south-facing patio(courtyard).



Figure 6(a). Thermal radiation simulation of a street building in a block fragment.

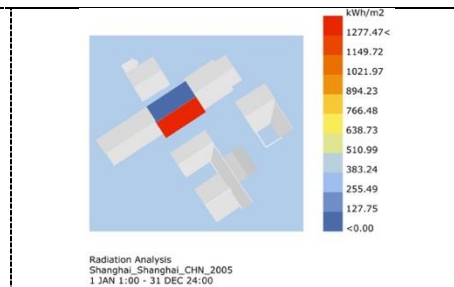


Figure 6(b). Thermal radiation simulation of a street building in a block fragment.

By increasing the connection between the inner courtyard and the street, the outdoor comfort degree of the block has been improved through the design. The comparison of the comfort degree of the plot before and after the design on the same day in summer in Table 1 below shows that the comfort time ratio has increased from 72.63% to 80.12%.

Table 1. The comparison of the average comfort in summer before and after design.

	Previous	Design
Result image		
percentage of time comfortable	72.6213592	80.1165049



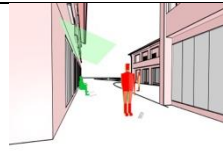



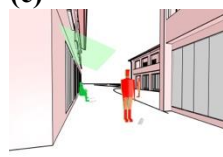


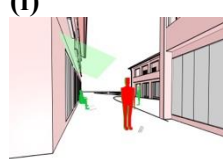
3.2. Street Space and Human Behavior and Comfort

Since ancient times, people have regarded the thermal environment as a determinant of behavior habits. People will use their wisdom to find the most environmentally friendly activities habits for different

periods of time and different climatic environments. By choosing different spatial nodes in the West Street block and analyzing the thermal imaging and human comfort at the same time, we can find that the thermal environment of different locations and different physical space forms is quite different. For example, Table 2 simulates the comfort degree of human body in different block spaces in May, July and September, and obtains the radiation heat of human body. It is found that even if the overall comfort degree is the worst in July-August, the human body will get more uncomfortable radiation in September because of the relationship between the height angle of the sun, and setting certain sunshade sketches or gray space in the block can effectively improve the comfort degree of human body.

At noon in summer, outdoors and patios are in a hot state, at which time most of the activities of tourists gather in the cooler streets. In the afternoon, when heat passes through the roof, the temperature of the second-floor room and the indoor begins to rise. Instead, people will choose the outdoor courtyard with strong ventilation.

Table 2. comfort degree of human body in different block spaces in May, July and September.

	9:00-10:00	12:00-13:00	15:00-16:00	Layout and Legend
May				 <div>Wh</div> <div><div></div><div>500.00<</div><div>450.00</div><div>400.00</div><div>350.00</div><div>300.00</div><div>250.00</div><div>200.00</div><div>150.00</div><div>100.00</div><div>50.00</div><div><0.00</div></div>
(a)	(b)	(c)		
July				
(d)	(e)	(f)		
Sept.				
(g)	(h)	(i)		

Since modern architecture, the use of mechanical technology can keep the indoor environment of our whole life, work and study in a unified comfortable condition, which makes the activities of different indoor spaces positioned according to the thermal environment become blurred. They can occur in the whole building, while the outdoor environment is difficult to achieve absolute mechanical control.

Too many choices lead to waste of energy. The research aims at the traditional block of West Street, and reserves and extends certain courtyard space, so that the thermal environment changes in different spaces of the building match with human activity habits and keep the relationship between the environment and civic culture. This will not only help to make the building environment truly adapt to the villagers' life, but also help to maximize the use of energy, so as to achieve the ecological and dynamic consistency of the street.

4. Conclusion

Firstly, at the level of solar energy and block ecology, it is found that the best direction of building lighting is south-to-east. In order to make most of the buildings have a better orientation, it is necessary to sort out the inner buildings in the northern area of the block. For the buildings with poor orientation but historical value, we should adjust the internal functions of the buildings and rectify the facades, increase the southern window opening, reduce the forced Eastern and Western window opening, and shade the western sun.

Then, in the aspect of wind energy and street ecology, through planning and design, the design attempts to open the long building interface of the historical pedestrian street to form the corridor of

natural wind and sunshine, so that the southeast dominant wind, good daylighting in the South and external airflow can enter the interior of the plot in summer. From the radiation analysis, ventilation comparison and comfort study of West Street Pedestrian Street, it is found that the road space parallel to the wind direction is helpful for ventilation and can effectively improve outdoor comfort in summer, while the road space vertical to the wind direction is not very ventilated. Therefore, the main wind direction ventilation lanes can be opened to a certain extent in historic districts, the natural ventilation inside can be increased, and the outdoor activity sites can be increased. The plan improves outdoor comfort through certain enclosure space and grey space setting, attracts residents to participate in outdoor activities, and reduces refrigeration energy consumption in summer.

Finally, the use of radiation analysis can effectively add greening and optimize plant allocation. The effective photosynthetic sunshine analysis in the outer space of the block was simulated by software, and the plant allocation strategy was obtained: the area with small solar radiation energy was suitable for planting shade-loving plants, and the area with slightly higher solar radiation energy was suitable for planting sun-loving plants. Historic blocks should increase the green area from plane to three-dimensional to improve the comfort of the streets.

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