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Research on Historical Spatial Evolution Assessment System and Protection Management Strategy of Ancient Cities Based on Spatial Data Mining Technology

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ABSTRACT

In today's society, ancient cities, as important components of historical and cultural heritage and urban development, are receiving increasing attention for their protection, utilization, and management. This research mainly focuses on the construction of an evaluation system for the spatial historical evolution of ancient city streets and the corresponding management strategies. Through a comprehensive evaluation of the spatial issues and characteristics of the ancient city streets, a multi-dimensional evaluation system for the historical evolution of the ancient city space with a total of 13 indicator factors, including historicity, is constructed. Taking Suzhou Ancient City as an example for empirical analysis, five typical types of ancient city streets are identified. Finally, corresponding update strategies are proposed for different types, especially the utilization of biomaterials and the design of plant landscapes, providing more innovative and sustainable management suggestions for the revitalization planning of the ancient city.

Keywords: Ancient city space, Indicator factors, Evaluation system, Management strategy, Historical scenery, Resident functions

1. Introduction

The ancient city is a cultural heritage, carrying rich historical information and cultural connotations. With the acceleration of urbanization, ancient city spaces are facing various challenges and difficulties [1]. To better protect and utilize the ancient city space, achieve sustainable development and vitality reshaping of the ancient city, the evaluation of the historical evolution of the ancient city space and research on management strategies have become hot topics. Wang Z et al. conducted a study on the current development issues of the ancient city of Anyang in Henan Province, China, through field research and questionnaire surveys. They proposed the feasibility of solving these problems from the perspective of management philosophy and technology, thereby clarifying the development direction of the ancient city [2]. Ziyi et al. used the ancient city of Luanzhou in Tangshan City, Hebei Province as an example to

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discuss the importance of restoring and protecting ancient towns for inheriting cultural backgrounds, achieving economic transformation, revitalizing the tertiary industry, building strong counties, and improving people's lives. And the weights and scores of different elements were calculated using yaahp software, the changes in their spatial quality were evaluated, and suggestions for improving spatial quality were proposed [3]. These research results provide rich theoretical support and practical experience for the inheritance and development of ancient cities. In view of this, research constructed an evaluation system for the historical evolution of ancient city space, evaluating the ancient city from four dimensions: history, culture, scenery, and function. Moreover, based on the evaluation results, strategic suggestions were proposed for the spatial management of the ancient city, hoping to achieve sustainable development of the ancient city. The innovation of the research lies in the construction of an evaluation system that includes four dimensions: history, scenery, residents, and function, and is refined into 13 specific indicator factors, providing a scientific and systematic basis for the evaluation of the ancient city street space. Not only did the evaluation analysis be conducted, but the evaluation results were also directly applied to the formulation of renewal strategies for streets, achieving a close combination of theory and practice.

2. Quantitative research and value analysis methods for the space of ancient city streets

The ancient city is a carrier of historical and cultural heritage, containing rich historical information and cultural heritage. By constructing an evaluation system and evaluating the street space of the ancient city, the characteristics and value of each element in the ancient city can be clarified, providing targeted suggestions for the protection of the ancient city [4-5]. This helps to preserve and inherit the historical and cultural heritage of the ancient city, enhancing the cultural heritage of the city. The research investigated the reconstruction management plans of many famous ancient cities, including Pingyao Ancient City, the Old Town of Lijiang, Dali Old City and so on, by consulting the literature related to the reconstruction management of ancient cities and visiting them. The current situation of street space in general ancient cities is influenced by local residents, geographical environment, and the history of the ancient city. To this end, based on the principles of integrity, feasibility, and resident openness, this study constructs a complete street space evaluation system from four dimensions: history, scenery, residents, and function, as shown in Figure 1.

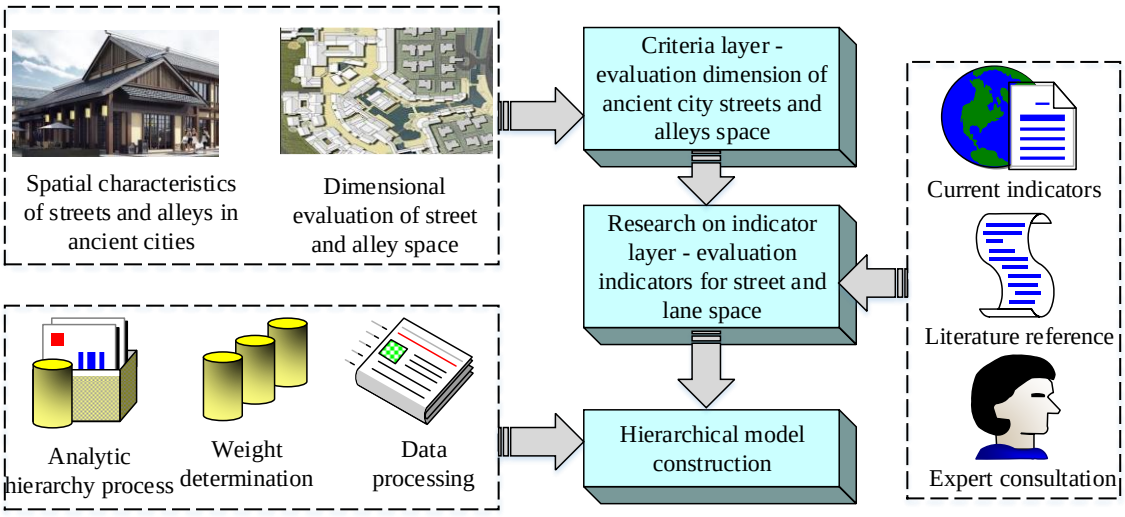


Fig. 1. Framework diagram for constructing the spatial evaluation system of ancient city streets

As shown in Figure 1, the Analytic Hierarchy Process (AHP) was used in the study to determine the criteria layer for street space evaluation and the evaluation dimensions of ancient city street space by sorting out the local legal evaluation system and protection regulations. The details are denoted in Figure 2.

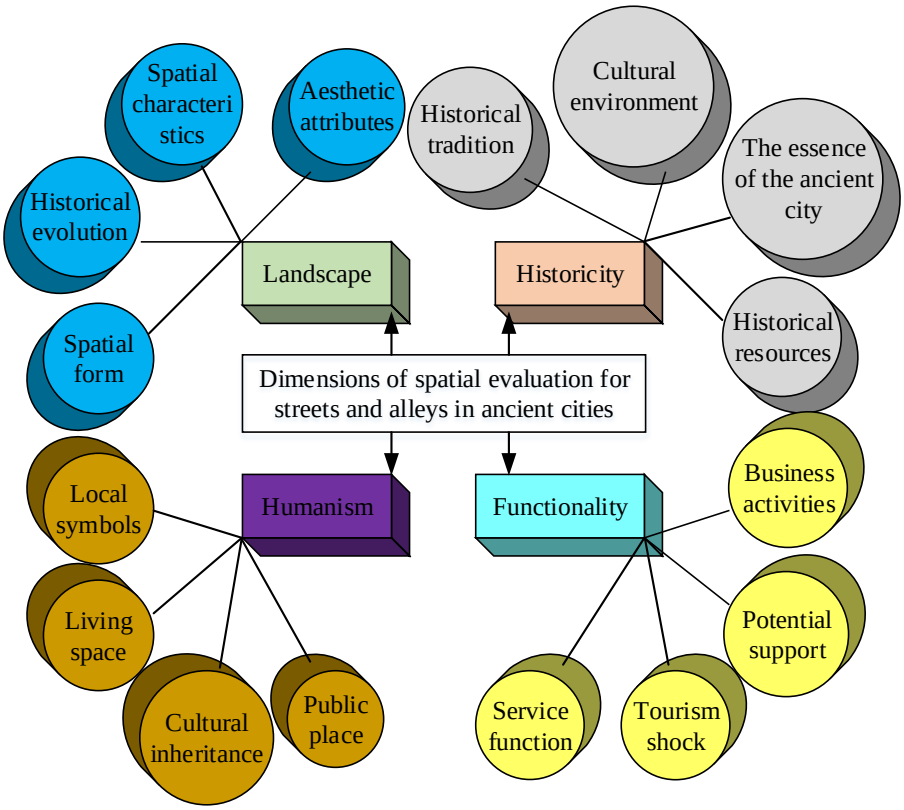


Fig. 2. Evaluation dimensions of street space in ancient city

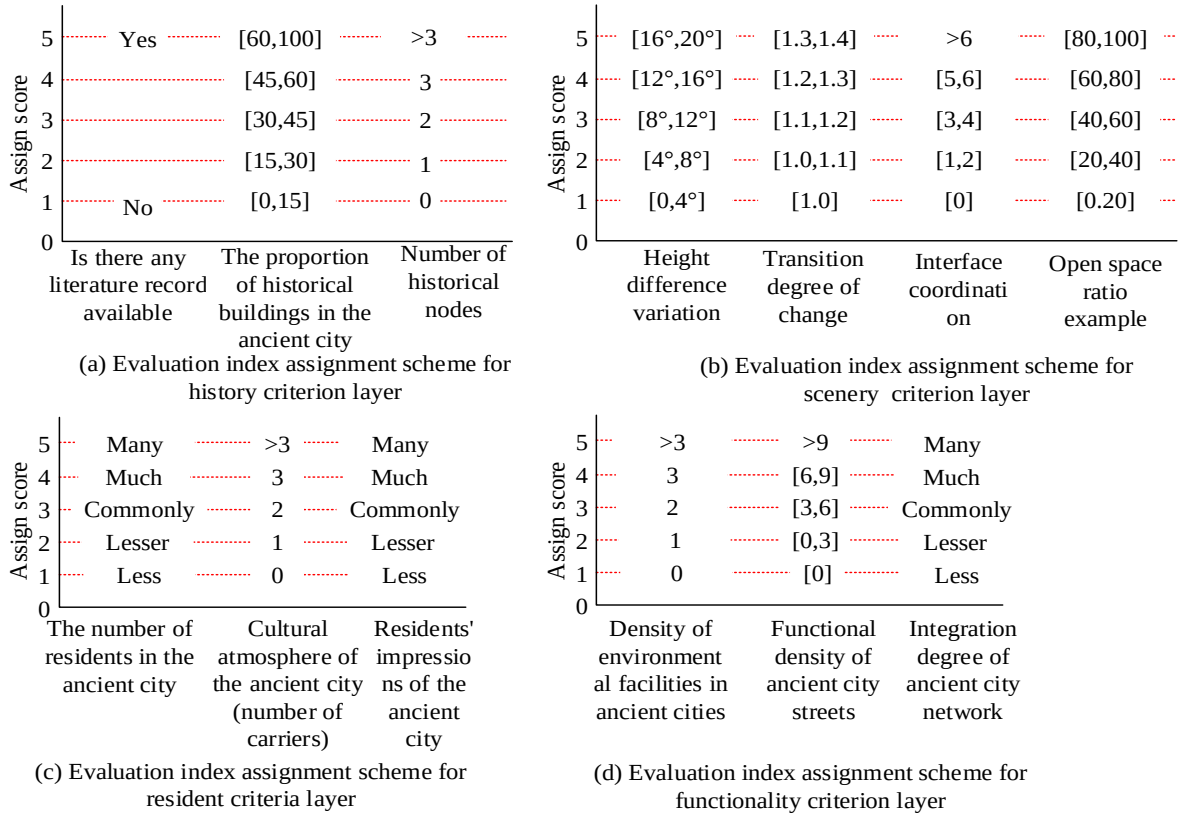
As shown in Figure 2, the study establishes evaluation dimensions from four dimensions: history, scenery, residency, and function aspects of the ancient city. In terms of historicity, the historicity of ancient city streets is not only reflected in their layout and preservation of historical buildings, but more importantly, as inheritors and showcases of urban historical and cultural heritage, they carry rich historical heritage and cultural memories. In terms of landscape, the unique aesthetic attributes of the ancient city streets, coordinated with the surrounding geographical environment, form diverse spatial forms, and provide unique visual enjoyment for residents and tourists. In terms of residents, the ancient city streets, as important places for daily communication among residents, carry collective memories and a sense of identity, reflecting the inheritance and continuation of local culture. In terms of functionality, the ancient city streets have become the core areas for urban traffic and commercial activities, and are even more important service spaces in tourism development, providing important support for the economic development and social activities of the city. By integrating these four dimensions, it can gain a more comprehensive understanding of the characteristics and importance of ancient city streets, and provide more targeted suggestions and measures for the planning and protection of ancient cities. Based on the analysis of the four important dimensions of the ancient city and the review of relevant literature, 36 evaluation indicators have been preliminarily organized. 10 experts in ancient city architecture and relevant architects were hired to summarize and evaluate the evaluation indicators. The evaluation indicators for the street space of the ancient city were obtained. Table 1 shows the details.

Table 1. Spatial evaluation indicators for ancient city streets

Evaluation dimension	Evaluation indicator	Evaluation method	Data acquisition method
Historicity	Longevity of history	Using literature records to measure	Local historical literature review
	Historical building proportion	%	Local historical literature review
	Number of historical nodes	Each	Local historical

			literature review
Scenery	Environmental quality of ancient cities	Measuring the proportion of open spaces in ancient cities	Conduct investigations locally
	The degree of spatial changes in the streets of the ancient city	Height difference variation	Conduct investigations locally
		Transition degree of change	Conduct investigations locally
	Interface coordination measurement	Measuring the integrity, height, and volume of ancient city architecture	Conduct investigations locally
Resident	Degree of cultural inheritance	Investigate the history and culture of the ancient city, the number of carriers, historical figures, cultural background, etc	Conduct investigations locally
	The number of residents in the ancient city	Number of survey participants	Conduct investigations locally
	The sense of identification among the residents of the ancient city with its culture	Investigate the local residents' sense of identification with the culture of the ancient city	Conduct surveys locally and conduct resident surveys
Functionality	Functional density of ancient city streets	POI points for plot service industries, plot public space services, and plot transportation locations, used to calculate the density of each plot	Conduct investigations locally
	Density of environmental facilities in ancient city streets	Investigate the number of environmental facilities per unit area of the ancient city	Conduct investigations locally
	Integration degree of the ancient city street network	Calculate the ratio of the number of road segments in the ancient city street network to the maximum possible number of road segments	Conduct investigations locally

The data acquisition methods required in Table 1 are divided into three types. The first type is interest point data. The study uses web crawler software to crawl data heatmaps related to the target ancient city from the network, and sequentially evaluates the functional density and population flow of the target ancient city [6]. The second type is field observation data, which involves conducting field research on the target ancient city, recording and analyzing historical resource points, related buildings, and pedestrian flow data of the ancient city. The third type is survey questionnaire data, which aims to understand the subjective evaluation and impression of the street by the residents of the target ancient city through interviews and questionnaire surveys [7]. The three-dimensional spatial structure of the ancient city is relatively complex. For intuitive analysis and calculation, the study simplifies complex street spaces into one-dimensional linear spaces and assigns corresponding attribute information on the axis. Thus, effective road network data for ancient cities is formed. Combined with existing GIS technology, it quantitatively analyzes the spatial position, distribution, and relationship of simplified street axes [8-9]. The weights calculated by the AHP are utilized to comprehensively evaluate the street space. Finally, the evaluation results will be applied to the street classification and updating strategy to achieve precise and effective street spatial management. To quantify the evaluation system of the constructed ancient city street space, research was conducted on assigning weights to evaluation indicators, as shown in Figure 3.



(a) Evaluation index assignment scheme for history criterion layer

(b) Evaluation index assignment scheme for scenery criterion layer

(c) Evaluation index assignment scheme for resident criteria layer

(d) Evaluation index assignment scheme for functionality criterion layer

Fig. 3. Assignment scheme for four dimensional criterion layers

Figure 3 (a) shows the assignment scheme of the history criterion layer, where the literature records are obtained by querying the county annals and relevant literature. The first historical node includes temples, former residences of celebrities, famous buildings and other buildings that exist in the ancient city, and the second is natural objects such as ancient trees, wells, and stones. Historical buildings mainly include ancestral halls, former residences of celebrities, and other buildings. Figure 3 (b) shows the assignment scheme of the scenery criterion layer, which mainly evaluates the scenery from two aspects: the street morphology and visual features of the ancient city. The characteristics of street morphology are the degree of elevation variation and turning point variation of the ancient city. The visual characteristics are the coordination of the cross-section and the proportion of open space in the ancient city. Figure 3 (c) shows the evaluation index assignment scheme for the resident criterion layer, where the number of residents in the ancient city is estimated based on the data heatmap. Evaluating the cultural atmosphere and residents' impression of the ancient city can provide a deeper understanding of the cultural value of the streets in the ancient city. Figure 3 (d) shows the evaluation index assignment scheme for the functionality criterion layer. Functionality analysis needs to comprehensively consider the facility support and accessibility conditions along the ancient city, fully tap into the economic potential of the street, and enhance the tourism and life service functions of the entire ancient city.

3. Analysis of the results of the spatial evaluation system for ancient city streets - taking Suzhou ancient city as an example

3.1. Data sources

When constructing the spatial evaluation system for Suzhou ancient city streets, a diversified data source was used to ensure the comprehensiveness and accuracy of the results. 1. Spatial image data: Obtain high-resolution spatial images of the ancient city of Suzhou through remote sensing technology and GIS system. 2. Street photography and field research: To gain a deeper understanding of the actual situation of the ancient city streets, researchers conducted street photography and field research. 3. A questionnaire survey

and interviews: first-hand information on street facilities, environmental hygiene, and residents' daily lives was collected. Historical documents and archives: Suzhou, as a cultural city with a long history, has rich historical documents and archives. Relevant information on urban planning, architectural design, historical and cultural aspects was consulted to understand the historical evolution and cultural background of ancient city streets. 4. Statistical data: Obtain statistical data on population, economy, transportation, and other aspects of Suzhou Ancient City from government departments. 5. Expert opinions and public feedback: During the evaluation process, 30 experts in ancient city renovation, professors in architecture, and engineers were collected for their opinions, and public opinions and feedback were widely solicited.

3.2. The determination results of the weights of various indicators in Suzhou ancient city

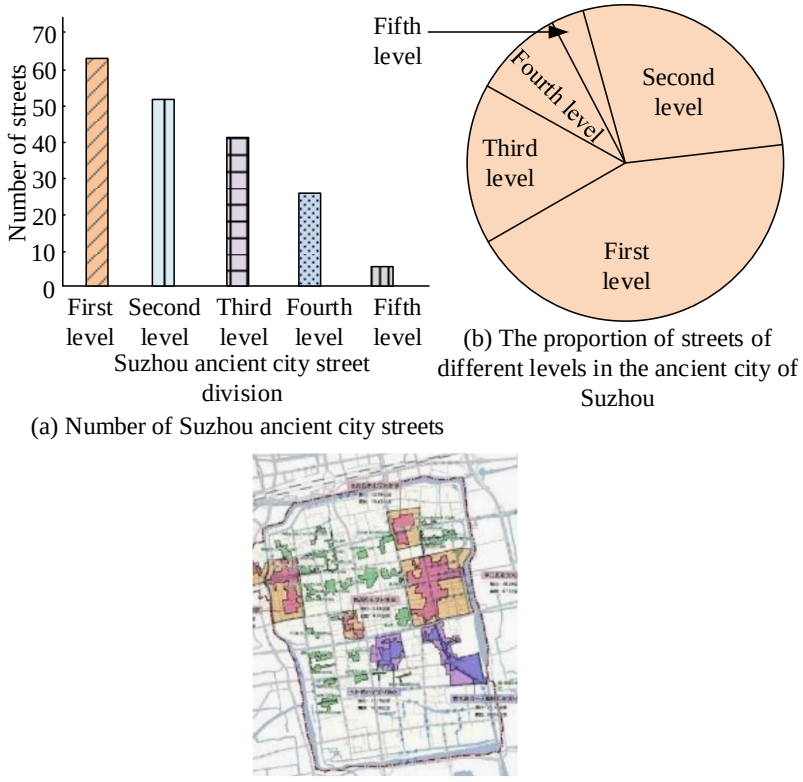
The research focused on the criteria layer and indicator layer factors, and used theoretical modeling to set evaluation indicators, constructing an evaluation system for the street space of Suzhou ancient city. In the selection of criteria layer indicators, combined with historical literature and the actual situation of Suzhou ancient city, it is necessary to emphasize the importance of the history and scenery aspects of the ancient city, and moderately increase the weight of resident and function aspects. Therefore, history (0.453)>scenery (0.301)>resident (0.142)>function (0.104) should be set. In terms of determining the weight of the indicator layer factors, the study adopted the paired comparison method to construct a comparison matrix, to obtain the indicator weight of the evaluation system for the ancient city street space. The results are shown in Table 2.

Table 2. Indicator weights of the spatial evaluation system for ancient city streets

Weight of historicity indicators					
Historicity	Longevity of history	The proportion of historical buildings in the ancient city	Number of historical nodes in the ancient city		Weight
Is there any literature record	1	2	3		0.174
The proportion of historical buildings in the ancient city	1/2	1	1/3		0.301
Number of historical nodes in the ancient city	1/3	3	1		0.525
Weight of scenery indicators					
Scenery	The ratio of open spaces in ancient cities	Degree of variation in street height difference	Street turning degree	Coordination degree of ancient city interface	Weight
The ratio of open spaces in ancient cities	1	1/2	1/3	1/4	0.281
Degree of variation in street height difference	2	1	1/2	1/2	0.214
Street turning degree	3	2	1	1/3	0.227
Coordination degree of ancient city interface	4	2	3	1	0.278
Weight of resident indicators					
Resident	Degree of cultural inheritance	The number of residents in the ancient city	The identity of ancient city culture		Weight
Degree of cultural inheritance	1	3	5		0.621
The number of residents in the ancient city	1/3	1	2		0.223
The identity of ancient city culture	1/5	1/2	1		0.156
Weight of functionality indicators					
Functionality	Function density of ancient city streets	Density of environmental facilities in ancient city streets	Integration degree of the ancient city street network		weight
Function density of ancient city streets	1	4	2		0.521
Density of environmental facilities in ancient city streets	1/4	1	3		0.234
Integration degree of the ancient city street network	1/2	1/3	1		0.245

3.3. Multidimensional evaluation results of Suzhou ancient city street space

3.3.1. Historicity. According to the survey results, there were 38 artificial nodes in the ancient city of Suzhou, covering historical buildings such as Guandi Temple, Baozhi Temple, Chenghuang Temple and other cultural relics. The natural nodes included 11 natural landscapes such as Xiaozhi Stone and Bijia Stone. The historical buildings in the ancient city of Suzhou are mostly from the Ming and Qing dynasties. Based on the survey results and weight assignment, the obtained data was graded to obtain the evaluation results of the historical dimension of Suzhou ancient city street, as shown in Figure 4.



(a) Number of Suzhou ancient city streets

(b) The proportion of streets of different levels in the ancient city of Suzhou

(c) Distribution map of streets at different levels in the ancient city of Suzhou

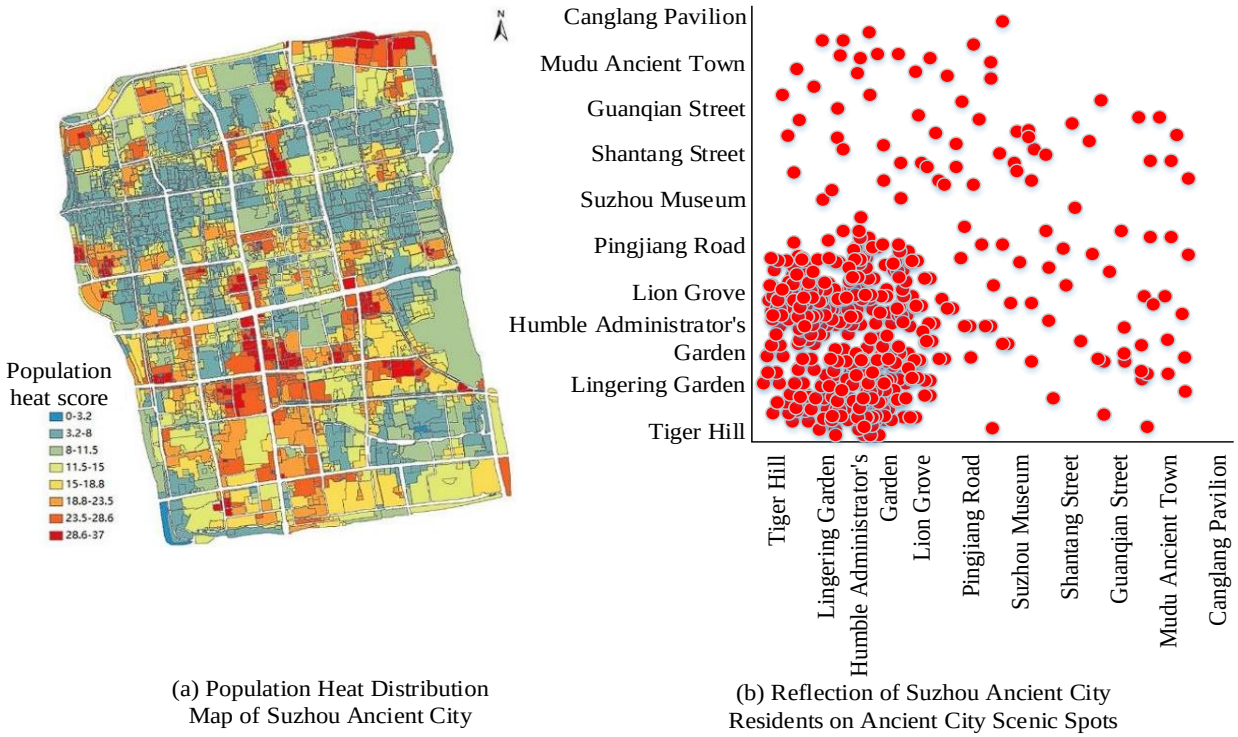
Fig. 4. Evaluation results of historicity dimensions of Suzhou ancient city street

According to Figure 4, there were 63, 52, 41, 25, and 4 historic first, second, third, fourth, and fifth level streets located in the ancient city of Suzhou. They accounted for 34.05%, 28.11%, 22.16%, 13.51%, and 2.17% respectively. The first and second level streets are historically low value areas, while the third, fourth, and fifth level streets were historically high value areas. According to the distribution map, historical low value areas are mainly distributed in the edge and peripheral areas of the ancient city of Suzhou. The width and length of these streets may be relatively large to meet the needs of modern transportation and urban planning. They connect the ancient city area with the external areas and are an important link for urban development. At the same time, these streets also carry the modern atmosphere and development vitality of the ancient city of Suzhou, making important contributions to the prosperity and development of the city. The historical high-value areas are mainly distributed in the central area of Suzhou ancient city and near major transportation arteries. These places are the historical core areas of urban development, with densely packed street layouts. These streets carry the rich historical culture and resident memories of the ancient city of Suzhou, and are important places for tourists and citizens to experience the charm of the ancient city.

3.3.2. Scenery. Similarly, the scenic beauty of Suzhou ancient city is comprehensively evaluated based on the classification of street turning changes, the degree of spatial height difference changes, the proportion of street open spaces, and the coordination of the entire street interface. There are 24, 18, 12, 9, and 3 first, second, third, fourth, and fifth level streets in Suzhou ancient city, respectively. The scenic high value areas of Suzhou ancient city are mainly concentrated in the center and south of the city, such as historical blocks such as Pingjiang Road and Shantang Street. The streets in these areas have rich transitions and moderate changes in spatial height differences, retaining the unique charm of the ancient city while meeting the comfortable needs of modern walking. The proportion of open space on the street is appropriate, providing sufficient rest and communication space for citizens and tourists. At the same time, the coordination of the street interface is very high, and the antique architecture is integrated with modern elements. The low value scenic areas are mainly concentrated in the edge areas of ancient cities

and blocks constructed in modern times. The streets in these areas have fewer changes in turning points, and the spatial height difference may be too large or too small, resulting in a lack of hierarchy and rhythm in the street space. The insufficient proportion of open space on the street makes it appear crowded and oppressive. At the same time, the coordination of the street interface is relatively low, and the architectural style may not be unified, which affects the overall landscape effect of the street. The streets in these low value areas have to some extent affected the overall image of Suzhou ancient city, and also reduced the living and tourism experience for citizens and tourists. Therefore, subsequent renovations need to focus on renovating these low value areas.

3.3.3. Resident. The study used a data heatmap to analyze the population of Suzhou ancient city, and conducted a questionnaire survey to investigate the impressions and evaluations of the top ten famous ancient place names of Suzhou ancient city by local residents. The results are shown in Figure 5.



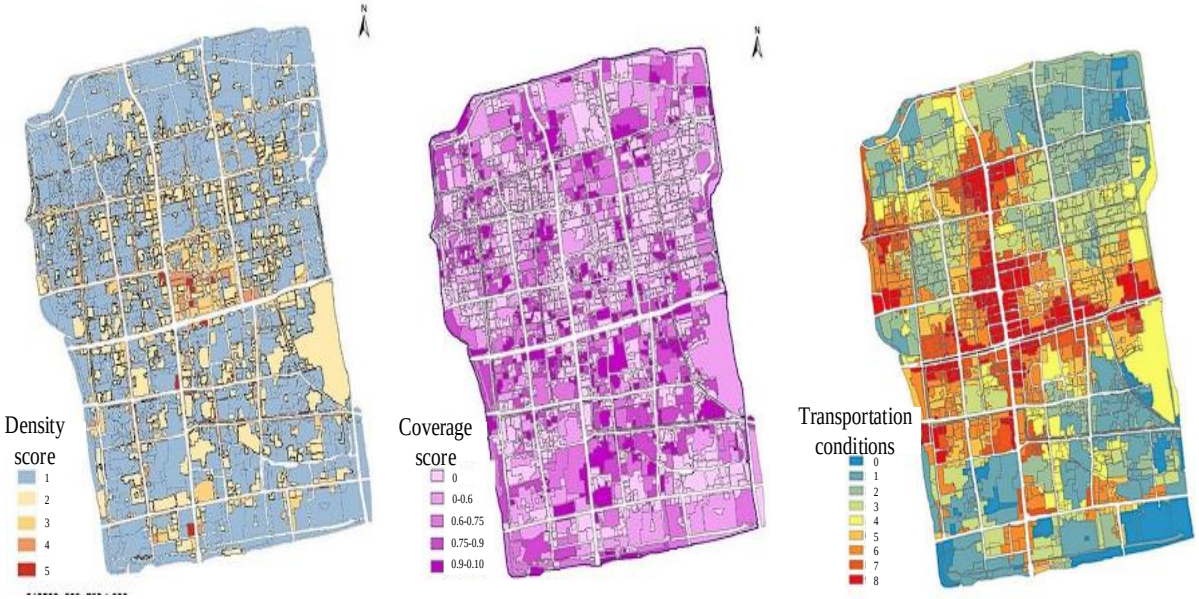
(a) Population Heat Distribution Map of Suzhou Ancient City

(b) Reflection of Suzhou Ancient City Residents on Ancient City Scenic Spots

Fig. 5. Evaluation results of residential dimensions in Suzhou ancient city street

As shown in Figure 5 (a), the densely populated areas of the ancient city of Suzhou are mainly concentrated in the center and south of the city. As shown in Figure 5 (b), the top three most memorable ancient city attractions for local residents in Suzhou are Huqiu, Liuyuan, and Humble Administrator's Garden. These attractions are mainly concentrated in the central area of the ancient city. This indicates that the core area of the ancient city is a densely populated and culturally rich area, which is crucial for enhancing the tourist experience and urban image.

3.3.4. Functionality. Crawling the POI points for service industries, public space services, and transportation location of the Suzhou ancient city plot is to evaluate the street functional density of the ancient city. The results are shown in Figure 5.



(a) Service Industry of Suzhou Ancient City Plot

(b) Public Space Services for Suzhou Ancient City Plot

(c) Transportation Location of Suzhou Ancient City Plot

Fig. 6 Evaluation results of functional density of Suzhou ancient city streets

From Figure 6 (a), the distribution of service industries in the ancient city of Suzhou showed a trend of slightly higher in the north than in the south. Among them, the Guanqian community in the central part of the ancient city is the most densely populated area for service industries, while secondary roads and main streets such as Tangjia Lane and Yangyu Lane are also places where service industries are more concentrated. As shown in Figure 6 (b), due to the dense road network and numerous public spaces in the central part of the ancient city, its service coverage rate was significantly higher than that of the outskirts of the ancient city. The southern part of the ancient city has a slightly higher service coverage rate than the northern part due to the large number and uniform distribution of public spaces. According to Figure 6 (c), the transportation locations on both sides of the rail transit line in the ancient city of Suzhou and the area near the moat of the Bachelor's Community were relatively superior, while the transportation locations in the northeast, southeast, and southwest corners were relatively weak.

3.4. Classification and application of spatial evaluation results for Suzhou ancient city streets

The four dimensions of Suzhou ancient city interact with each other to obtain five types of ancient city streets, as shown in Figure 6.

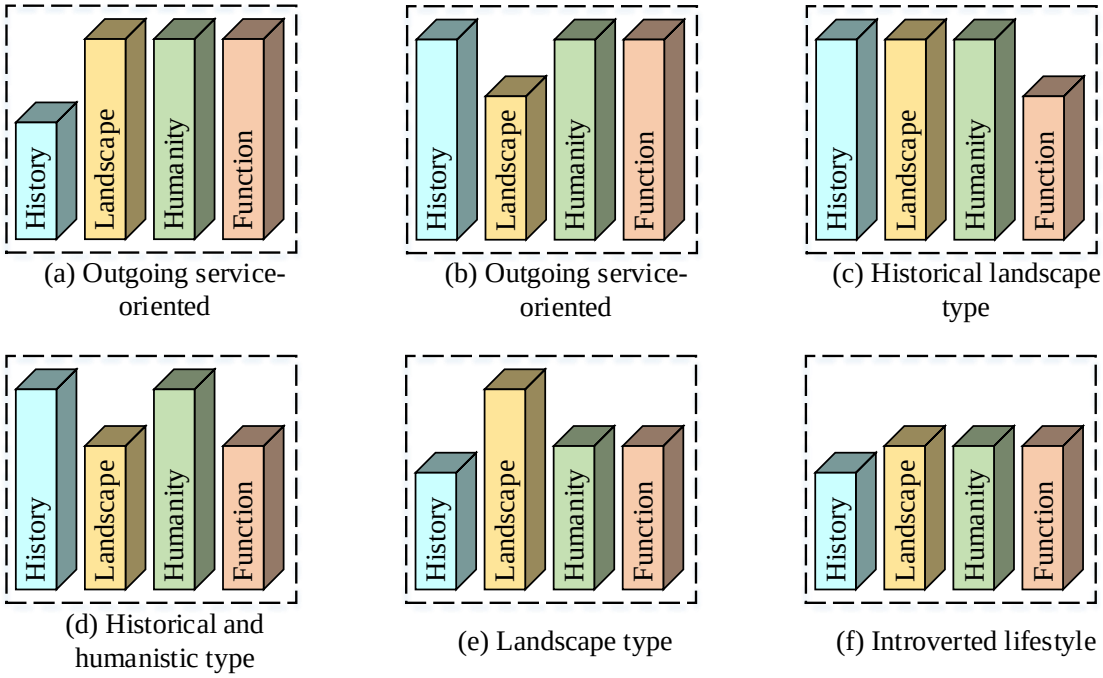


Fig. 7. Five types of ancient city streets

As shown in Figure 7, the streets in the ancient city are divided into five types based on the proportion of different dimensions. The historical landscape type is characterized by high historical and scenic features, and these streets play a supporting role in connecting the north and south in the development of the ancient city. The historical resident type is mainly characterized by high historicity and high residency. In the process of updating, protecting historical resources and revitalizing vitality are key to maintaining the traditional style of the ancient city and revitalizing the memory of residents. The geographical landscape type is mainly characterized by high scenic features, but low residential and historical significance. These streets are mostly located in the northern part of the ancient city, connecting important nodes by maintaining natural terrain and scenic environment and utilizing scenic features. The outward oriented service model is based on high functionality and is mostly located in the southern part of ancient cities, with dense commercial activities. Introverted lifestyle is mostly located inside ancient cities, mainly used for daily transportation and household needs. During the update process, it is necessary to maintain the alleyway space, improve environmental quality, and meet the daily needs of the indigenous people.

4. Management strategies for ancient cities based on evaluation results

4.1. Historical scenery type and historical residential type

The research proposed method was used to identify streets with high historical and cultural value in the ancient city, and different protection strategies were developed based on the historical and cultural value of the streets. The specific management strategies are shown in Figure 8.

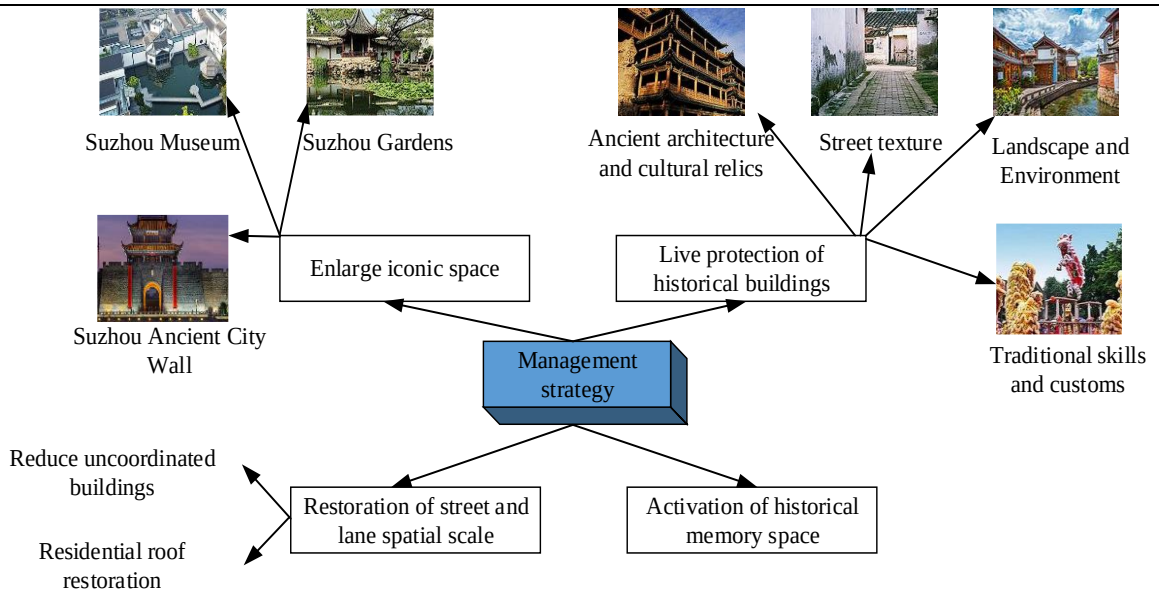


Fig. 8. Management strategies for historical scenic and historical residential ancient city streets

As shown in Figure 8, for the historic streets of ancient cities, management strategies are proposed from four aspects. The first is to form a complete protection system for the local ancient architecture, scenery, streets, environment, as well as traditional skills and customs. At the same time, it is also necessary to pay attention to the balance between protection and development, ensuring that historical buildings are properly protected while also being used by local residents to realize their social and economic value. For example, using bio-based coatings for the restoration and protection of ancient buildings has better durability and environmental friendliness. Using biotechnology to improve the materials of traditional handicrafts can increase the diversity and attractiveness of traditional culture in the ancient city. The second is to expand the influence of local iconic buildings, such as Suzhou gardens and Suzhou museums in the ancient city of Suzhou. Through biotechnology simulation of past ecological landscapes, their characteristics are expanded and their commercial value is increased. The third is to demolish and restore the uncoordinated and illegal buildings in the ancient city. The fourth is to attach importance to the places in the memory of indigenous people, preserve the cultural memory carried by historical and cultural spaces, and achieve sustainable development. Using biotechnology to develop bio-based products (such as bio-based artworks) with the characteristics of the ancient city can promote the emotional inheritance of the ancient city.

4.2. Geographical scenery type

For ancient city streets with distinctive geography, the first step is to maintain the local natural terrain and landforms of the ancient city, which includes strengthening vegetation coverage, preventing soil erosion and desertification, and respecting and protecting the mountain environment. In this regard, research suggests introducing plant species that are suitable for the local environment of the ancient city, using biological soil stabilization technology to stabilize surrounding mountains and prevent soil erosion. At the same time, advanced biodegradation technology is utilized to treat polluted soil and water sources, ensuring the ecological function of the ancient city. Secondly, it is necessary to create a diverse street landscape, preserve historical walking methods, integrate idle spaces along the street, add gardens and recreational facilities that are suitable for the ancient city, and fully utilize the roofs of buildings for biological greening to enrich the scenic surface of the ancient city streets, making the street scenery more diverse and attractive.

4.3. Outward service-oriented

Outward service-oriented streets should integrate multiple functions such as culture, history, commerce, tourism, and public services, enhance interaction and efficiency, and enhance the versatility of facilities and

social sustainability. The functional implantation should be "continuous in style and tailored to local conditions", protect historical buildings, implant "light commercial" functions, and develop characteristic commerce on buildings with commercial potential. The specific implantation content is shown in Figure 9.

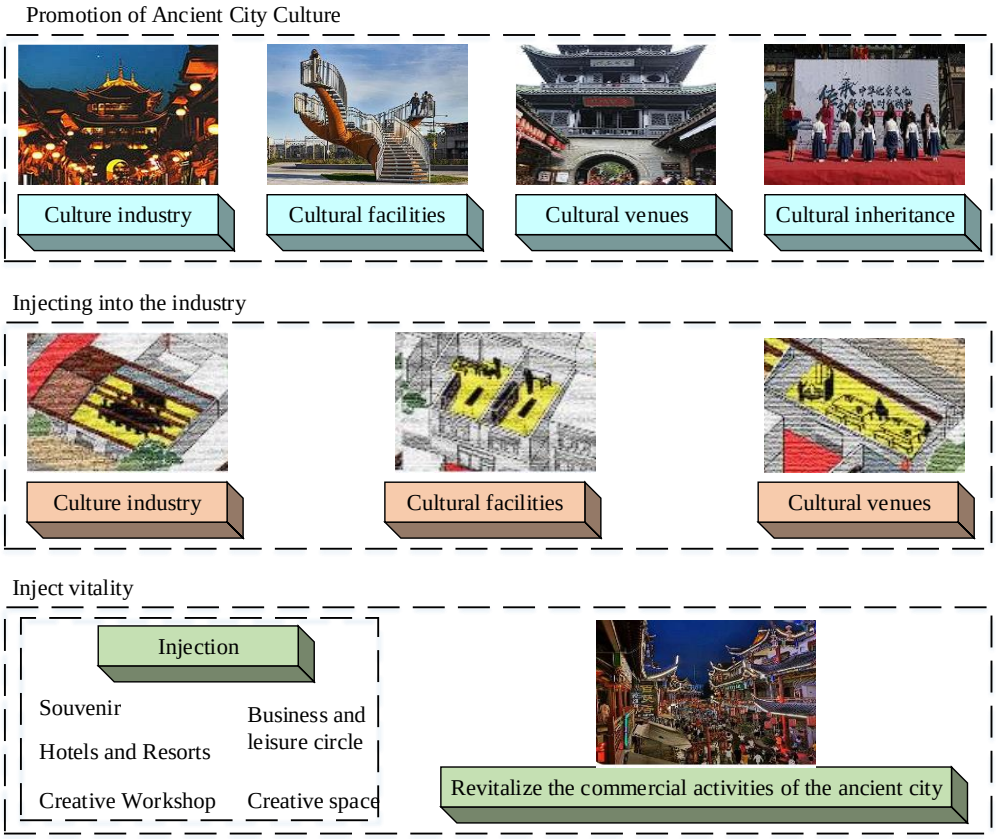


Fig. 9. Schematic diagram of the implantation of commercial culture in the ancient city

When implanting, it is also necessary to highlight the characteristics of the ancient city and avoid homogenization of "commercial streets". By combining local culture, cuisine, sea views and other resources, a cultural image with the characteristics of an ancient city can be created. Firstly, commercial biotechnology is utilized to deeply explore and inherit the distinctive culture of the ancient city streets. Secondly, biotechnology is applied to improve and cultivate local specialty ingredients, enhancing their quality and taste, and creating a food brand with ancient city characteristics. At the same time, combining the geographical environment and climatic conditions of the ancient city streets, biotechnology is utilized to develop ecological agriculture, providing tourists with healthy and delicious food choices, and promoting the economic consumption of the ancient city.

4.4. Inward oriented living type

The inward oriented living type ancient city streets solve the problems of insufficient public space and environmental quality through methods such as infrastructure implantation, utilization of idle space, building vacation, and spatial function replacement, while retaining the diverse spatial characteristics of the streets and adding daily fun. The concept of "small-scale and gradual" protection and inheritance is advocated. Through micro renewal and transformation, it guides residents to update and improve their living environment on their own without damaging the ancient city's appearance, achieving common prosperity in space, industry, culture, and life.

5. Conclusion

Scientific evaluation of the ancient city space can more accurately grasp the characteristics and problems of the ancient city streets, and provide effective strategies and directions for future urban renewal and development. To this end, a comprehensive and scientific street space evaluation system was constructed, covering a total of 13 indicator factors from four dimensions, and a systematic evaluation was conducted using Suzhou ancient city as an example. According to the evaluation results, the ancient city of Suzhou was divided into five street types: historical resident type and geographical scenery type. A comprehensive to single update management strategy was proposed for different types of ancient city streets. These strategies aimed to reshape the vitality of the ancient city of Tongshan and achieve scientific renewal and development of its street space. However, the indicators selected for constructing the research system are mostly selected from an objective perspective, and there are relatively few emotional indicators for local residents. Subsequent research will focus on this aspect of indicators.

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