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Research on Evaluation and Optimization Mechanism of Soundscape Pattern Based on Urban Cultural Ecological Space Protection

Qianwen Wang[1]
School of Architecture, Tianjin University
No. 92 Weijin Road, Nankai District, Tianjin,P.R.Chnia 300072

Zhongjian Shen[2]
School of Architecture, Tianjin University
No. 92 Weijin Road, Nankai District, Tianjin,P.R.Chnia 300072

Chen Liang[3]
School of Architecture, Tianjin University
No. 92 Weijin Road, Nankai District, Tianjin,P.R.Chnia 300072

Siyuan Ding[4]
School of Architecture, Tianjin University
No. 92 Weijin Road, Nankai District, Tianjin,P.R.Chnia 300072

Jian Zeng[5]
School of Architecture, Tianjin University
No. 92 Weijin Road, Nankai District, Tianjin,P.R.Chnia 300072

ABSTRACT

With the change of sound comfort standards, the quality of sound environment is no longer limited to the control of noise and sound loudness reduction, and harmonious sound environment has become an increasingly livable part of the city. At present, the research on soundscape environment is mostly focused on the spatial types of parks and communities, while the research on the urban cultural ecological space, a special type of urban space, is still insufficient.

Based on the principle of Soundscape evaluation, this paper takes China's Bazhou City as an example to construct the protective scope of cultural ecological space and its soundscape database through GIS platform.By using the mathematical model of "grey statistical theory"+"fuzzy comprehensive evaluation" and digital technology simulation, the composition of soundscape resources in cultural ecological protection space is analyzed in detail, the spatial distribution characteristics and interaction relationship between cultural ecological space and soundscape are

[1] 346343255@qq.com
[2] 619445503@qq.com
[3] liangc1015@163.com
[4] 478754233@qq.com
[5] 13602058416@vip.163.com

revealed, and the specific optimization mechanism is proposed，so as to provide reference for the design and transformation of the soundscape of urban cultural ecological space.

Keywords: Soundscape, cultural ecological space protection, evaluation, optimization mechanism

1. INTRODUCTION

At present, in the urbanization stage where economic growth is the priority in China, most of the local cultures representing diversity are ignored or negated in urban construction. This is not only alienated from the natural environment, but also the "museum-like" protection mechanism makes cultural resources separate from the background of inheritance and presents a limited static cognitive state. Under the trend of mass loss of traditional culture, China has adopted special policies other than mainstream economic concepts to initiate cultural innovation in the field of cultural ecology protection. The policy starts from the law of cultural development, respects the diversity and complexity of culture, from point to point, uses holistic and systematic thinking, and improves the ability of cultural governance. As a part of building a harmonious city, the sound environment should be taken into consideration by the scale of civilization.

Based on this, Bazhou, a typical small city in northern China, is selected as the research object. With the background of local and regional cultural ecological space, SPSS, GIS, and other tools, the pattern of cultural ecological protection was determined by spatial analysis method, and the urban cultural ecological protection area was delineated. The study of the coupling relationship between its spatial characteristics and the soundscape environment was regarded as an experiment to create an ecological environment conducive to the healthy and sustainable development of culture from the scale of the soundscape and played an active and exemplary role in the development of urban culture. At the same time, according to the distribution characteristics of soundscape with different functions, this paper put forward the implementation mechanism of soundscape optimization with universal cultural ecological protection space, aiming at exploring the multi-dimensional interaction between urbanization development and culture, ecology and sound environment.

2. DELIMITATION OF CULTURAL ECOLOGICAL PROTECTION AREAS

Bazhou City is located in the eastern part of the central Hebei Plain, north latitude 39.06, east longitude 116.24. Bazhou has a long history; it belonged to Guangyang County in the Qin Dynasty and belonged to Zhuojun County in the Han Dynasty. During the Song and Liao Dynasties, Bazhou became an indispensable place for military strategists because it was situated at the throat of traffic and water transportation between the north and the south. In February 1990, with the approval of the State Council of China, the county was transformed into a county-level city under provincial jurisdiction.

2.1 Characteristics of Bazhou cultural ecology system

The cultural ecosystem is composed itself and the ecosystem in which culture emerges and develops. Specific cultural types are often associated with specific ecological characteristics and form a unique cultural ecological system. Therefore, the elements contained in the cultural ecosystem include natural resources, social culture, and other aspects, and these elements interact with each other to form a complex and pluralistic cultural ecological system.

According to the sorting and screening of more than 320 elements related to the cultural and ecological system in Bazhou, the following characteristics were summarized from the types and spatial distribution of resources:

（1）In terms of resource types, one category is the primary ecological factors that breed and carry culture, including terrain, soil, water resources, vegetation, farmland, resources, ecological sensitivity, etc. The other is the cultural elements to enhance the connotation of the value of ecological resources, including intangible cultural elements in the form of arts, skills, customs, and other significant ways, and material cultural elements in the form of historical sites, historical blocks and monuments. Among them, 38 are essential material cultural elements, mainly in northern residential buildings, historical blocks and temples and ancestral temples; 17 are non-material cultural elements, mainly in local concerts, martial arts and handicrafts.

（2）In terms of spatial distribution, there are many rivers recorded in Bazhou from ancient to modern times. Water and land transportation is smooth. Therefore, the cultural elements that have long been inherited mainly depend on the water area to be preserved and extended in four directions, which constitutes the unique human and terrestrial environment for the growth and development of excellent folk culture in Bazhou City and its inheritance from generation to generation. Cultural elements with common characteristics are more concentrated in areas with regional resource characteristics of Bazhou, such as the MangNiu River and Bazhou Geothermal Field, to provide a more active and open platform for the display of Bazhou culture.

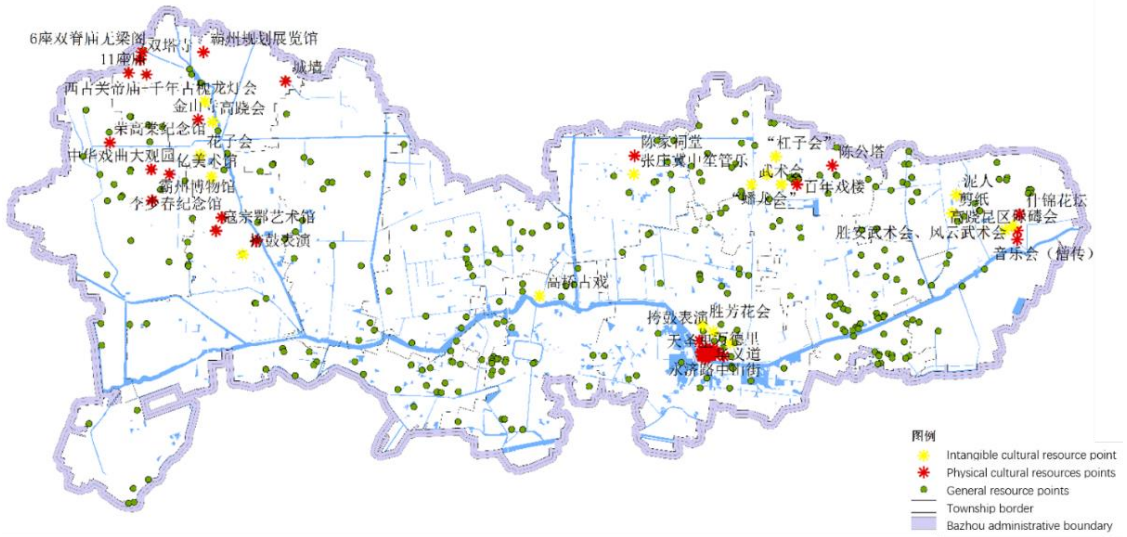

Figure 1 Distribution Map of Cultural and Ecological Resources in Bazhou City

2.2 Spatial delimitation of cultural ecological protection areas

According to the spatial distribution characteristics of cultural element value evaluation, combined with each element of the basic natural layer, including the topographic factor, vegetation factor (grassland, woodland, garden land), farmland factor and ecological sensitivity factor, the weights of each factor were calculated by YAAHP platform. Finally, the factors of the cultural element layer and the primary natural layer were superimposed with the help of overlay analysis of GIS. At last, the Bazhou cultural ecological protection area was delimited.

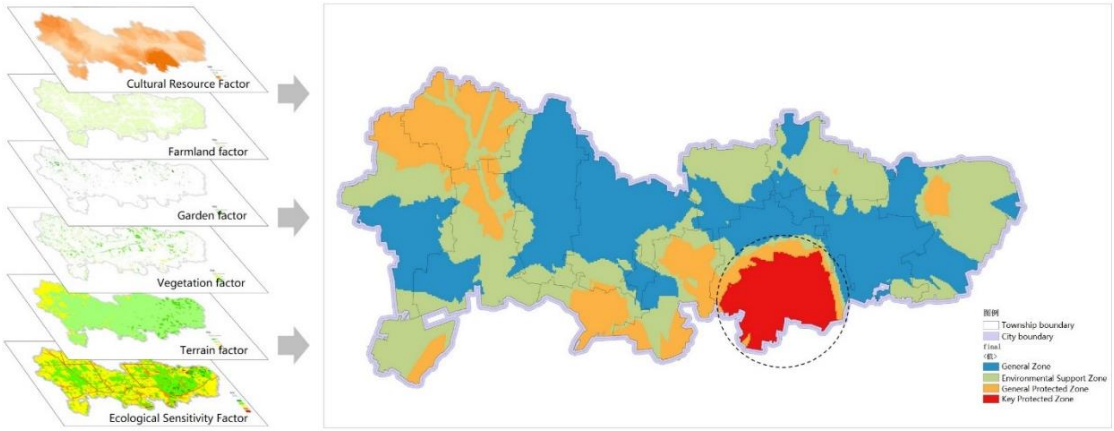

Figure 2 The superposition of various factors of cultural ecology and the delimitation of cultural ecology protection space

3. COMPOSITION AND DISTRIBUTION OF SOUNDSCAPE IN CULTURAL ECOLOGICAL PROTECTION AREA

3.1 Composition of Soundscape Resources

It is taking the delimited cultural ecological protection area as the research scope. According to the attributes and characteristics of the selected cultural ecological protection space, the preferences of residents and tourists for the sound environment of the area, and the field survey of the area, the resource elements that constitute the soundscape of the area were divided into two categories: positive soundscape and negative soundscape. Among which the positive soundscape included 7 categories and 19 subcategories. The negative soundscape included 5 categories and 8 subcategories.

Table 1 Pre-selection of Soundscape Indicators in Cultural ecological Protection Area

Soundscape types	Component Elements of Soundscape	Pre-selected indicators
Positive Soundscape	Water soundscape	Slow flow of the river
		The Sound of Dripping water
		The Sound of rapid stream
	Rain soundscape	The Sound of thin rain
		The Sound of misty rain
	Wind soundscape	The Sound of gentle breeze
		Wind-blown coniferous forest
		Wind-blown broad-leaved forest
		Wind-blown bamboo forest
	Animal soundscape	birds sound
		Insect sound
		Frogs sound
		Cats sound
	Folklore soundscape	The sound of productive labor
		The sound of cultural performances
	Recreational soundscape	The sound of tourists playing
		The sound of vendors hawking their wares
	Artificial soundscape	The Sound of Broadcasting
		The Sound of electronic music
Negative Soundscape	Rain noise	The noise of rainstorm
		The noise of heavy rain

	Wind noise	The howling of the wind
		Wind blows the sound of doors and windows
	Thunder noise	The noise of thunder
	Animal noise	The noise of dogs barking
	Artificial noise	Traffic noise
		The noise of machines

The questionnaire was designed according to the classification, and the importance of each index in the region was judged by Richter's 7-grade scoring method (Level 1 is not important. Level 7 is important. Level 2 to 6 is between the two). Also, experts who have been engaged in the research of protection and ecological restoration of historical and cultural areas for a long time are invited to independently judge the importance of each indicator from the perspective of the soundscape and to screen out the sound elements that had a core impact on cultural ecological protection areas.

The importance of the evaluation index of the soundscape in cultural ecological reserve was divided into 3 categories: high, medium and low, and the whitened functions in grey leagues of each grade were constructed. The specific formula was shown below:

The first type is "high degree of importance", which is assigned to k=1, and the function expression is:

$$f_1(mn)=\begin{cases}1 & r_{mn}\geq 7\\ \dfrac{r_{mn}-4}{7-4} & 4<r_{mn}<7\\ 0 & r_{mn}\leq 4\end{cases}$$

The second type is " medium degree of importance", which is assigned to k=2, and the function expression is:

$$f_2(mn)=\begin{cases}0 & r_{mn}\geq 7\\ \dfrac{7-r_{mn}}{7-4} & 4<r_{mn}<7\\ 1 & r_{mn}=4\\ \dfrac{r_{mn}-1}{4-1} & 1<r_{mn}<4\\ 0 & r_{mn}\leq 1\end{cases}$$

The third type is " low degree of importance ", which is assigned to k=3, and the function expression is:

$$f_3(mn)=\begin{cases}0 & r_{mn}\geq 4\\ \dfrac{4-r_{mn}}{4-1} & 1<r_{mn}<4\\ 1 & r_{mn}\leq 1\end{cases}$$

In the formula :(1) $f_k(mn)$ refers to the whitened functions value of the m-th evaluation index whose importance degree is n-level grade; (2) k stands for grey class number, k=1，2，3……，27. r_{mn} refers to the judge value of the m-th evaluation index whose importance degree is n-level grade, m= 1,2,3..., 7;n = 1,2,3...27.

The function expression of grey decision coefficient is:

$$\eta_k(m) = \Sigma g(mn) \cdot f_k(mn)$$

In the formula: $\eta_k(m)$ refers to the m-th evaluation index belonging to the k-th grey decision coefficient, g(mn) represents the number of experts who have made g(mn) represents the number of experts who have made n-level judgments on the m-th

evaluation index judgments on the m-th evaluation index, $f_k(mn)$ is the function value calculated by the whitened functions in grey leagues.

The decision vector of each primary indicator consists of three gray decision coefficients (η_{high}, η_{medium} and η_{low}). Based on the category corresponding to the maximum value of the grey coefficient in the decision vector, this study selected the index of "high" grade as the degree of importance and obtained the difference table of the degree of importance of each index affecting the soundscape quality of cultural ecological protection area. The specific results were shown in the following table:

Table 2 Grey Statistical Analysis on the Importance of Component Elements of Soundscape in Cultural ecological Protection Area

Component Elements of Soundscape	Pre-selected indicators	Decision vector			Degree of importance	Choose or not
		H_{high}	H_{medium}	H_{low}		
Water soundscape	Slow flow of the river	10.00	8.67	1.33	High	Yes
	The Sound of Dripping water	10.00	8.33	1.33	High	Yes
	The Sound of rapid stream	9.00	10.33	0.67	Medium	No
Rain soundscape	The Sound of thin rain	6.33	10.67	3.00	Medium	No
	The Sound of misty rain	7.33	11.33	1.33	Medium	No
Wind soundscape	The Sound of gentle breeze	9.67	9.33	1.00	High	Yes
	Wind-blown coniferous forest	9.00	10.33	0.67	Medium	No
	Wind-blown broad-leaved forest	12.00	7.33	0.67	High	Yes
	Wind-blown bamboo forest	12.67	6.33	1.00	High	Yes
Animal soundscape	Birds sound	13.67	6.00	0.33	High	Yes
	Insect sound	9.67	9.33	1.00	High	Yes
	Frogs sound	7.33	11.00	1.67	Medium	No
	Cats sound	1.33	9.67	9.00	Medium	No
Folklore soundscape	The sound of productive labor	3.67	11.67	4.67	Medium	No
	The sound of cultural performances	12.67	6.33	1.00	High	Yes
Recreational soundscape	The sound of tourists playing	5.33	13.00	1.67	Medium	No
	The sound of vendors hawking their wares	3.00	11.33	5.67	Medium	No
Artificial soundscape	The Sound of Broadcasting	9.33	8.33	2.33	High	Yes
	The Sound of electronic music	2.67	7.33	10.00	Low	No
Rain noise	The noise of rainstorm	8.33	7.67	4.00	High	Yes
	The noise of heavy rain	6.67	8.67	4.67	Low	No

Wind noise	The howling of the wind	9.00	8.33	2.67	High	Yes
	Wind blows the sound of doors and windows	6.67	8.67	4.67	Low	No
Thunder noise	The noise of thunder	4.67	11.00	4.33	Medium	No
Animal noise	The noise of dogs barking	7.67	10.00	2.33	Medium	No
Artificial noise	Traffic noise	14.00	4.67	1.33	High	Yes
	The noise of machines	15.00	4.00	1.00	High	Yes

According to the screening results of grey statistical analysis, the elements of the soundscape in the region showed the following characteristics. There were 8 main factors that influenced the positive and negative landscapes of cultural ecological protection areas, including water soundscape, wind soundscape, animal soundscape, folklore soundscape, artificial sound, rain noise, wind noise, and artificial noise. Among them, only 37.5% were human sound elements. This result showed that although human resources are generally considered to be an essential part of cultural ecological protection space, the natural soundscape is still a key factor affecting the soundscape conditions of cultural ecological protection space.

The 3 natural soundscapes included in the positive soundscape were mainly moderate sounds, while the 2 artificial soundscapes were mainly to highlight the humanistic atmosphere in the cultural ecological protection space, which was the key to creating the vitality of the space. The inconsistency between artificial noise and the environment was a prominent feature in the negative sound scene. Traffic noise was an unavoidable sound to improve the regional function, but because of its event and loudness, it became a more prominent negative sound in the region. The formation of natural noise is mainly due to the geographical location and climatic conditions of Bazhou itself. There are no mountains, hills, low terrain, gently tilting from northwest to southeast. The cultural ecological protection area is located in the eastern windy and sandy area. It is hot and rainy in summer and windy in spring. Therefore, seasonal wind noise and rain noise become negative natural sound affecting the sound environment in this area.

3.2 The regular pattern of Spatial Distribution

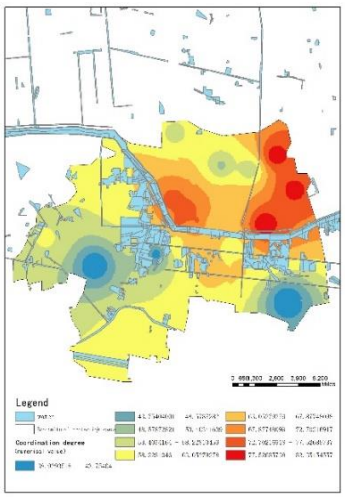

Figure 3 Coordination degree

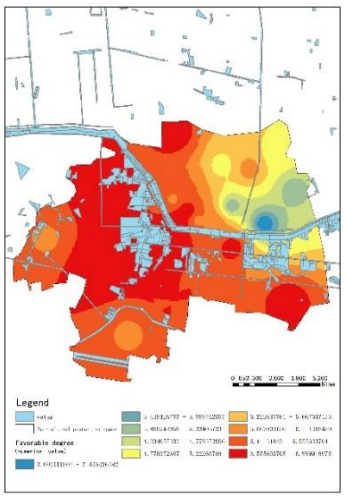

Figure 4 Favorable degree

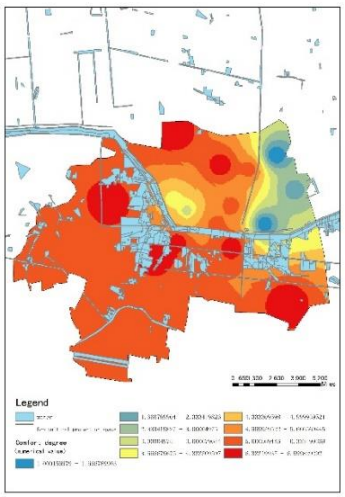

Figure 5 Comfort degree

The soundscape coordination degree was measured at 20 observation points in the region, and the data were imported into GIS software. The soundscape coordination degree distribution map of cultural ecological protection areas was drawn by interpolation calculation. It can be seen from the diagram that the river bounded the coordination degree of the soundscape in the region, showing the spatial distribution characteristics of high in the north and low in the south. In the industrial heritage area of the northeast, the sound level of the whole area was the highest because some manufacturing factories had not been completely shut down. The sound level of the historic block in the central part was at the medium level, and the trend of decline to the outside was slower. And the sound level of the ecological wetland relying on the river in the south was the lowest.

The favorable degree of soundscape sensibility was carried out by SPSS tools, and the survey data were imported into GIS for calculation, and the regional soundscape favorable degree map was drawn. It can be seen from the map that people had the highest preference for the soundscape in the large area of the wetland area in the south of the river, which was dominated by natural sound sources, followed by the core area of the historical block and the temple area. Comparing the data of the Coordination degree, the subjective evaluation of the three sensitivities was in a high-level area, and the coordination degree was quite different. It showed that the construction of sound environment sensitivities was not only determined by the level of sound but also closely related to the use of space.

Soundscape comfort survey data were also calculated to get the soundscape comfort degree map. The distribution of landscape comfort in the region was correlated with the sound level distribution, and with the ecological wetland and temple area, the surrounding area was gradually decreasing. Different from the spatial distribution of sound level, the average sound level of the temple area was higher than that of the ecological wetland, but the subjective evaluation was generally higher. It showed that the appropriate addition of sound types with better sensibility and comfort would make tourists more willing to stay here than that of the ecological wetland area with lower soundscape richness. The comfort degree of the neighborhood around the historic block was relatively low because the current neighborhood was still dominated by residents, except for some recreational facilities and cultural activities in the core block. Because of the wide range of sound radiation in the core area and the complex traffic conditions around it, the comfort of the residential area was reduced.

4. CONSTRUCTION OF SOUNDSCAPE COMFORT PATTERN

4.1 Computation of Soundscape Comfort Threshold

To further study the distribution characteristics of soundscape comfort in cultural ecological protection areas, data acquisition, and secondary analysis were carried out at the 20 observation points above, and the patches represented by the observation points were rated for soundscape comfort. The rating results were divided into five categories: very comfortable, relatively comfortable, general, relatively uncomfortable, very uncomfortable.

Based on the measured and investigated soundscape data, the membership degree of "very comfortable" and "very uncomfortable" in soundscape comfort perception was set to 1 and 0 by using the membership function of fuzzy mathematics. To highlight the interference of noise to the regional sound environment, the interval between "very comfortable" and "general" membership degree was set to 0.3 and between "general" and "very uncomfortable" membership degree was set to 0.2. Using the comfort probability formula:

$$P_i = \frac{\sum u_i n_{ij}}{\sum n_{ij}}$$

In the formula: n_{ij} is the frequency of occurrence of j subjective response corresponding to patch I of the observation point, u_i is the degree of membership of comfort of grade i, i = 1,2,... 14; j = 1,2,... 5.

Finally, according to the subjective and objective evaluation data of the regional soundscape comfort, the calculation formula of the comfort threshold E was used by using the method of fuzzy mathematics.

$$E = \frac{\sum L_i P_i}{\sum P_i}$$

In the formula, L_i is the arithmetic average sound pressure level of the patch I of the observation point, P_i is the comfort probability corresponding to observation point i, and the threshold of environmental comfort is calculated to be 66.43 dB.

4.2 Construction of Soundscape Pattern

Based on the resource conditions of the cultural ecological protection areas, and from the perspective of soundscape design, the local space was divided into five functional areas combined with the elements and characteristics of the soundscape. The spatial distribution law of soundscape and the calculation of the comfort threshold of soundscape environment, and the optimal design was carried out according to the specific and differentiated characteristics.

(1) Soundscape maintenance core area.

Mainly refers to the critical bearing area of cultural ecological protection space, which has mostly commercial, residential and cultural entertainment functions. It is the cultural essence of the whole area. The current situation of noisy business activities and noisy life mix, which not only covers the natural sound of the riverside but also reduces the comfort of the residents living in the neighborhood. In the soundscape design, the function area can implement the traffic mode of separating pedestrians and vehicles, open up a separate pedestrian passage, and limit the sound of car whistle, mechanical start-up, and reduce the interference of traffic noise to the sound environment in the area. In principle, we should reduce unnecessary commercial sounds, protect the natural

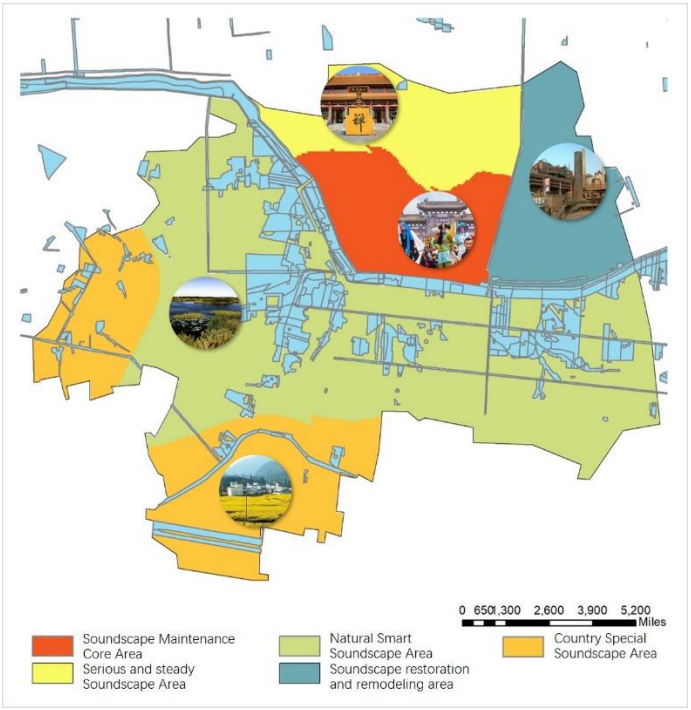

Figure 6 Construction of Soundscape Pattern

soundscapes of waterfront, create pleasant cultural sounds and fully build the core soundscapes of cultural ecological protection areas.

(2) Soundscape restoration and remodeling area.

This area is mainly composed of industrial heritage and some residential areas. The main sound source in this area is some factories that have not stopped production. The overall soundscape conditions are not optimistic. However, from the perspective of historical and cultural protection, the industrial heritage in this region is a product of history, has high historical value, and is also an important recreational resource of industrial heritage parks in the future. Therefore, the sound scene design in this area is mainly to restore and rebuild, control the sound level of noise enterprises, and do a good job of isolation, to accurately create industrial sound for the closed enterprise. To awaken the local industrial historical memory, and set up a dynamic recreational space, using industrial sound to foster a recreational atmosphere, so that sound and space complement each other.

(3) Natural smart soundscape area.

It mainly refers to the ecological wetland area in the south of the river. The region is dominated by natural sounds and is a rare source of the soundscape. In this area, ecological protection is the main factor, so it is not suitable to do too much manual intervention. Walking trestle can be planned to guide the flow of people in the core area to its hinterland so that people can transition between history and nature. On the premise of protecting the real natural sounds, landscape sketches should be built appropriately to increase the time for people to stop and listen to nature adequately.

(4) Serious and Steady soundscape area.

It is mainly composed of temple buildings. There were some nodes with heavy noise in living and traffic. The main activities in the area were sacrificial meditation, commemorative exhibitions, etc. Concentrative explanations, Hawking or dinners will be prohibited to minimize the sound of life. The quiet atmosphere and natural sound environment should be protected, the sound of history and culture should be added appropriately, and the diversity of soundscape in the functional areas should be enriched.

(5) Country-specific soundscape area.

This area is mainly the native villages in the South and north of China. The sounds in this area were mainly composed of the folk voices of the aborigines'daily production and life. These voices have become part of the village culture and should not be interfered too much. Soundscape experience areas can be set up appropriately, such as the experience of local farmers'working voice, street vendors' shouting, women's singing voice, etc. and closely combined with the characteristics of cultural ecological space, from the perspective of the soundscape to shape folk culture.

5. OPTIMIZING MECHANISM OF SOUNDSCAPE PATTERNS

The purpose of delimiting cultural ecological protection areas is to protect the process of preservation, inheritance, and dissemination of cultural ecosystems. Its impact on people is not only from the visual perspective but also from the auditory category. Through the study on the construction of spatial soundscape pattern for cultural ecological protection areas in Bazhou City, the optimization mechanism of spatial soundscape pattern was discussed.

Firstly, the design of the sound environment should be integrated into the thought of people-oriented and sustainable development. Through the construction of the database of the special soundscape resources in the cultural ecological space, and the experience and recognition of the people, the core influencing factors can be screened. Combining with the spatial distribution characteristics of the functional zoning of the space itself and

the coordination degree map, favorable degree map and comfort degree map of the soundscape, the pattern of the soundscape should be constructed, and the targeted optimization design should be carried out.

Secondly, the noise buffer should be defined according to the sound comfort threshold. The threshold of soundscape comfort in the Bazhou Cultural Ecology protection area is 66.42 dB. The calculation results can be used as the basis for improving and harnessing the soundscape, as well as the calculation results of the comfort threshold of the soundscape. The noise buffer zone can be drawn by using the noise simulation software, and the beautiful soundscape can be built as part of the regional protection planning.

Thirdly, excavate the city impression from the perspective of the soundscape. When investigating and counting the resources of cultural ecological reserves, sound resources should be included in the statistical list. We can use a multivariate analytical method to analyze the elements of the spatial soundscape, analyze the relationship between the characteristics of soundscape and the spatial function of matter, and strengthen the dialogue between sound and spatial function which has a positive impact on the construction of the public image. Make the soundscape design has a positive significance for the protection of regional unique sound culture and the overall impression of the regional soundscape.

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