

Soundscape Creation of the Lanzhou Yellow River Waterwheel Garden from the Perspective of Historical Soundscape Restoration

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Abstract: Against the backdrop of rapid urbanization, the protection of heritage soundscapes faces severe challenges. As a typical water-conservancy heritage site in northwestern China, the Lanzhou Yellow River Waterwheel Garden has witnessed a decline in place recognition as historical sound sources—such as the mechanical sounds of waterwheels and boatmen’s work chants—have disappeared, and the sonic symbols that carry collective memory now confront a crisis of rupture. Current research on heritage soundscapes remains limited by insufficient attention to the cultural value of historical soundscapes and an overreliance on physical noise reduction in conservation methods. Taking the Lanzhou Yellow River Waterwheel Garden as its research object, this study employs documentary archaeology, oral history interviews, and acoustic measurement to uncover the elements of its historical soundscape and to diagnose the underlying causes of soundscape rupture, including the erasure of soundscapes in the physical environment, intergenerational gaps in cultural memory, and the absence of authenticity-maintenance mechanisms. The study proposes site-specific soundscape creation strategies and constructs a “soundscape–memory–space” model through low-tech interventions such as mortise-and-tenon transmission devices, pebble wind-chime arrays, and interactive soundscape node designs, thereby achieving the cultural translation of the historical soundscape and the restoration of the genius loci. This research offers a new pathway for the soundscape conservation of industrial heritage and provides a reference for the living inheritance of water-conservancy heritage in the Yellow River Basin.

Keywords: Soundscape creation; Yellow River Waterwheel Garden; Heritage conservation; Cultural memory; Low-tech intervention; Spatial narrative

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1. Introduction

As an important dimension of human environmental perception, the soundscape—a concept proposed in the 1960s—refers to “the acoustic environment as perceived, experienced, or understood by an individual, group, or community in a given context”^[1]. In recent years, soundscape research has evolved from a purely acoustic discipline into an interdisciplinary field integrating architecture, anthropology, and environmental

psychology^[2]. Against the backdrop of rapid urbanization, the soundscape conservation of historic spaces faces severe challenges. As a typical water-conservancy heritage site in northwestern China, the Lanzhou Yellow River Waterwheel Garden possesses historical soundscapes of pronounced regional character, such as the “creaking of waterwheels” and “raftmen’s work chants”, which are not only living testimonies of regional culture but also acoustic expressions of the symbiotic “human–water–technology” relationship^[3]. However, with the encroachment of modern traffic noise and the decline of traditional cultural practices, the traditional soundscapes of the Yellow River Waterwheel Garden—the core carrier of Lanzhou’s reputation as the “City of Waterwheels”—including the mechanical sounds of the waterwheels, the flow of the Yellow River, and folk antiphonal singing, are fading and have led to a decline in place recognition. These sonic symbols bearing collective memory now face a crisis of rupture.

The main limitations of current research on heritage soundscapes are as follows. First, most studies focus on optimizing the contemporary acoustic environment and pay insufficient attention to the cultural value of historical soundscapes^[4]. Second, conservation methods for heritage and historical soundscapes tend to rely heavily on physical noise reduction, lacking an organic integration of technical measures with cultural narrative. This research gap leaves places such as the Yellow River Waterwheel Garden—which combine industrial heritage value with ecological landscape value—trapped in a dilemma of “prioritizing the material over the immaterial” in soundscape conservation and creation.

From the perspective of historical sound restoration, and guided by Norberg-Schulz’s theory of genius loci and UNESCO’s Convention for the Safeguarding of the Intangible Cultural Heritage, this paper constructs a systematic framework for soundscape creation in the Lanzhou Yellow River Waterwheel Garden^[5,6]. The study addresses three core questions:

- (1) How to uncover the historical soundscape elements of the Waterwheel Garden through documentary archaeology and oral history;
- (2) How the modern noise environment affects the perception and transmission of historical soundscapes; and
- (3) How restoration strategies can achieve the cultural translation of historical soundscapes. By integrating methods such as soundscape archaeology, acoustic measurement, and participatory design, this study aims to explore a new pathway for the soundscape conservation of industrial heritage.

2. Research object

This study takes the Yellow River Waterwheel Garden section in Chengguan District, Lanzhou, as its research object, focusing on the distinctive historical sonic environment formed by the waterwheel irrigation system since the Ming and Qing dynasties and on its contemporary rupture. The Waterwheel Garden is located in the western section of Binhe Road in Lanzhou, adjacent to Zhongshan Bridge to the east, the “Mother of the Yellow River” sculpture to the west, facing Baitashan (White Pagoda Hill) Park to the north and Baiyun (White Cloud) Temple to the south, making it an important node of the Yellow River Scenic Corridor. The history of the Lanzhou Waterwheel Garden can be traced back to the Jiajing reign of the Ming dynasty (1556), when Duan Xu, a jinshi degree holder from Lanzhou, created the waterwheel by adapting the noria (bamboo-tube waterwheel) technology of Yunnan. Drawing on the hydrological characteristics of the Yellow River, Duan Xu refined the design, and the first waterwheel was erected on the north bank of the Yellow River outside Guangwu Gate for farmland irrigation, giving rise to the place name “Waterwheel Garden”. By the late Qing dynasty, waterwheels stood in large numbers along both banks of the Yellow River, reaching 157 wheels; at their peak in 1952, the number increased to 252 wheels, irrigating an area of 100,000 mu

(approximately 6,667 hectares), which earned Lanzhou the reputation of the “City of Waterwheels”. After the 1950s, electric irrigation gradually replaced the traditional waterwheels, and the waterwheels disappeared. In 1994, to protect the cultural heritage, the Lanzhou municipal government rebuilt the Waterwheel Garden in the western section of Binhe Road and restored a pair of antique waterwheels. As shown in Figure 1 creating a cultural landscape integrating exhibition, tourism, and education. As the largest and most complete traditional waterwheel settlement extant in northwestern China, this riverside site not only carries the material production memory of “the creaking of waterwheels answered by the chorus of work chants” but also embodies the technical wisdom and ecological philosophy of “the joint force of nature and humankind” in the agrarian civilization of the Yellow River.

The existing waterwheel in the garden measures 16.5 m in diameter and is composed of a wooden mortise-and-tenon structure fastened without a single iron nail, demonstrating the exquisiteness of traditional craftsmanship. Its operation relies on the kinetic force of the Yellow River’s flow: during high-water seasons it is driven naturally, while in low-water seasons water is diverted and impounded by cofferdams; the buckets scoop up water and channel it through wooden troughs into the farmland, with a single wheel capable of irrigating up to 300 mu (20 hectares) per day. The functional zoning of the Waterwheel Garden comprises three main parts. The core exhibition area, centered on the twin waterwheels and supplemented by facilities such as a water-powered mill and cofferdams, reproduces the traditional irrigation scene. The cultural experience area includes a teahouse, a photography studio, and a folk-custom museum, enhancing the interactivity of visits through folk activities. The ecological landscape area consists of silt-deposited alluvial islands along the Yellow River and willow-shaded flats, complemented by landscape trails; the sections adjacent to urban traffic are planted with native vegetation such as Chinese willow (*Salix matsudana*) and tamarisk, forming a natural soundscape buffer zone.

By excavating the immaterial historical soundscape, this study addresses issues such as the coverage of historical sounds by traffic noise in contemporary urbanization and the cognitive gap regarding soundscapes among younger generations, exploring the feasibility of restoring the genius loci through low-tech soundscape installations. This study not only opens a new dimension for the living conservation of heritage but also constitutes a site-specific experiment in the revitalization of Lanzhou’s heritage.



Figure 1. Actual shooting of waterwheels in Lanzhou Waterwheel Garden.

3. Research methods

3.1. Documentary archaeology and oral history interviews

Historical records of the Waterwheel Garden's soundscape from the Ming and Qing dynasties to the Republican period were sorted out through ancient texts such as the *Annals of Lanzhou Prefecture* and the *Illustrated Investigation of Yellow River Water Transport*, from which core soundscape symbols—including “the creaking of waterwheels”, “raftmen's work chants”, and “market clapper sounds”—were extracted [7,8]. Questionnaires were administered to randomly selected elderly Lanzhou residents to record the keywords of their soundscape memories. Interviews were conducted with intangible cultural heritage inheritors of high professional competence and relevant professionals to collect their opinions on the effectiveness of soundscape creation strategies, from the perspective of historical sound restoration, in the living transmission of traditional skills.

3.2. Stratified questionnaire survey on restoration effectiveness

Questionnaires were designed for different groups, including elderly Lanzhou residents and tourists, to investigate issues such as the historical authenticity of the soundscape, from the initial extraction of soundscape elements to the evaluation of post-creation outcomes.

4. Composition and rupture of the historical soundscape of the waterwheel garden

4.1. Excavating historical soundscape elements

Historical soundscape elements mainly comprise material sound sources and symbolic soundscapes. Material sound sources include, but are not limited to, the creaking of Ming-Qing waterwheels, boatmen's work chants at the ferry, and the human voices of the market; symbolic soundscapes refer to the sounds of bells and drums in sacrificial activities and the sounds of festival folk customs.

Material sound sources are centered on the mechanical sounds of the waterwheel, whose acoustic characteristics can be deduced from ancient texts and physical remains. The *Annals of Lanzhou Prefecture* (Water Conservancy Section) records that “the water impels the wheel, and its creaking never ceases day or night” [7]. Combined with the illustrated descriptions of wooden waterwheel construction in *Tiangong Kaiwu*, it is inferred that the gear-meshing sounds are concentrated in the 200–500 Hz frequency range, with sound pressure levels of approximately 65–72 dB(A) [9].

Boatmen's work chants at the ferry constitute another core soundscape element. Described in the *History of Yellow River Water Transport* as “voices that pierce the turbid waves and harmonize with the water's rhythm”, spectrographic analysis of extant recordings of Tao River work chants shows that their fundamental frequency remains stable at 220 Hz $\pm 10\%$, and their rhythmic patterns are positively correlated with variations in the flow velocity of the Yellow River [10].

Market human voices map spatial vitality through soundscape density. The acoustic scene recorded in the Qing-dynasty *Annals of Gaolan County* as “the clamorous cries of peddlers and laborers” can be spatially reconstructed using the density of shop distribution at the historical wharf site (approximately 12 shops per 100 m) and a sound pressure level attenuation model (6 dB per 10 m) [3].

In addition to the element extraction from the literature, the questionnaire survey of Lanzhou residents also showed that the sound of the Yellow River's flow (75%), the sound of waterwheel operation (81%), and boatmen's work chants (48%) are widely recognized as the core soundscape symbols of Lanzhou's Yellow

River culture.

Because the constitution of symbolic soundscapes is closely tied to the local folk-cultural system, and because the Waterwheel Garden as the research object possesses prominent material sound-source characteristics, this study does not discuss symbolic soundscapes in detail.

4.2. The underlying causes of soundscape rupture

The soundscape rupture of the Lanzhou Yellow River Waterwheel Garden results from multiple dimensions of influence, as manifested in the following

4.2.1. The erasure of soundscapes in the physical environment

As the core element of the historical soundscape, the authenticity of the waterwheel's mechanical sound has been severely compromised by the cessation of the waterwheels. According to field measurements conducted in 2023, the equivalent sound level of the extant antique waterwheel is only 52.1 dB(A), a 24% reduction from the 68.5 dB(A) documented in historical records. Traffic noise from North Binhe Road (peak 79.5 dB(A)) exerts a significant masking effect in the 500–1000 Hz frequency band, which will inevitably reduce tourists' accuracy in recognizing the waterwheel sound. The impact of traffic noise was also prominent in the questionnaire survey: 75% of respondents were deeply impressed by traffic noise, and 61% mentioned the clamor of visitors, further corroborating the masking effect of North Binhe Road traffic noise (peak 79.5 dB(A)) and visitor activity sounds (peak 68.5 dB(A)) on the historical soundscape.

Meanwhile, the alienation of the spatial structure of the soundscape has exacerbated this phenomenon: the current layout of the riverside trails diverts the visitor route 200 m away from the axis of the historical wharf, breaking the interconnected soundscape system of waterwheel sounds and work chants and making it difficult for visitors to experience a complete and authentic soundscape during their tour.

4.2.2. Intergenerational gaps in cultural memory

In the oral history interviews, the recognition accuracy of historical soundscapes among the group aged over 70 (82%) was significantly higher than that of younger groups (17%). The questionnaire survey further verified this disparity: among respondents over 51, 68% could clearly describe the historical soundscape features of the Waterwheel Garden, whereas only 12% of the 18–30 age group chose “fairly familiar”. The intergenerational gap is especially evident in the recognition of “boatmen's work chants” (82% in the older group vs. 23% in the younger group), reflecting the rupture of the traditional soundscape memory chain.

4.2.3. The absence of authenticity-maintenance mechanisms

Soundscape conservation lacks an interdisciplinary coordination mechanism. Existing restoration strategies rely mostly on single technical measures such as noise barriers (with a noise reduction of 4.2 dB) and audio playback, neglecting the cultural-contextual associations of soundscape elements. The value of the historical soundscape lies not only in the transmission of physical sound waves but also in its social function as a “cultural resonator”: the intensity variations of sacrificial drum-and-music sounds (from 58 dB(A) at the opening of rituals to 82 dB(A) at their climax) correspond to the ebb and flow of collective emotion, and the spatiotemporal distribution of the market soundscape (with a peak sound pressure level of 68 dB(A) at the *chen* hour, i.e., 7:00–9:00 a.m.) reflects the exchange networks of agrarian society^[11]. When modern

interventions strip away these associative dimensions, the soundscape degenerates into a museumified sound specimen, losing its agency to activate collective memory.

5. Soundscape creation strategies based on the regeneration of waterwheel power

5.1. The site-specificity of soundscape creation

The site-specificity of soundscape creation is mainly manifested in the following aspects.

(1) Minimal intervention

The purely mechanical transmission structure of the traditional waterwheel is retained, and the soundscape installations are driven through reversible mortise-and-tenon connections, ensuring that all restoration measures are reversible and non-destructive to the heritage itself^[12].

(2) Material authenticity

Local materials such as Yellow River pebbles (10–20 cm in particle size), rammed earth (red clay with an 18% moisture content), and elm wood (density 0.68 g/cm³) are adopted to form a material dialogue with the texture of the historic environment, avoiding the erosion of the site's historicity by modern materials^[13].

(3) Living transmission

Oral history collection and audio archiving are carried out with the extant inheritors of boatmen's work chants; the recording process follows the ethical norms of the *Convention for the Safeguarding of the Intangible Cultural Heritage* and preserves the socio-contextual information of the soundscape (e.g., the usage scenarios of the chants and the roles of participants)^[6]. A blockchain-based soundscape database is established to achieve tamper-proof storage of cultural memory, providing sustainable resources for dynamic conservation^[14].

In response to the traffic noise problem raised by 75% of respondents, the restoration strategy prioritizes Chinese willow belts and soundscape zoning design over fully enclosed noise barriers, so as to preserve the openness of the site and its compatibility with the historic fabric.

5.2. Cultural memory-based translation of soundscape symbols

The restoration of the Waterwheel Garden's soundscape should take the "authenticity" and "integrity" of cultural heritage as its core principles^[15]. In terms of translation strategy, the principle of "low-tech intervention" is adopted: modified waterwheel mechanisms can drive wooden clappers, using traditional mortise-and-tenon craftsmanship to simulate the historical percussive rhythms, thereby avoiding the damage that electrical systems would cause to the integrity of the heritage itself. Meanwhile, arrays of Yellow River pebble wind chime metaphorically evoke hydrological rhythms, and the random colliding sounds of natural materials awaken the agrarian civilization's perception of time, elevating soundscape restoration from a technical issue to the reproduction of cultural meaning^[16].

5.3. Spatial narrative and the revitalization of heritage value

The spatial organization of the soundscape should respond to the genius loci of the Waterwheel Garden as an industrial heritage site^[17]. Along the historical axis of the waterwheels, a three-tier narrative sequence of "production–ecology–faith" is constructed. In the production zone, the mechanical sounds of the waterwheels form the core, while Chinese willow belts—plants documented in historical records as windbreaks and sand stabilizers—create a soundscape buffer zone, sustaining the traditional "waterwheel–vegetation" ecological

association while reducing noise. In the ecological zone, the superimposition of pebble wind chimes and the sound of the Yellow River's flow reconstructs a dynamic "soundscape–nature" dialogue. In the faith zone, interactive installations such as pedal-triggered chant players activate the ritual soundscape, with their spatial positioning strictly following the positional coordinates of the historical wharf site, ensuring the spatial isomorphism between soundscape events and material remains ^[2]. This linear narrative is not merely a reproduction of historical functions; through visitors' participatory experience, it realizes the "embodied transmission" of cultural heritage—by designing correlations between bodily actions and soundscape responses, such as sound pressure levels increasing with the number of participants, abstract cultural memory is transformed into perceptible place-based practice ^[18].

The questionnaire survey showed that 68% of respondents supported recreating the historical soundscape through soundscape installations, and the preference rate for interactive installations among the 18–30 age group reached 82%. On this basis, a "soundscape–memory–space" model—embodied in a "soundscape memory cabin at the waterwheel viewing platform"—can be designed to activate the soundscape. It employs mortise-and-tenon interactive installations (72% support) combined with visual symbols (58%) to enhance visitors' experience, effectively helping younger generations associate bodily memory with soundscape impressions.

6. Conclusion and outlook

This study systematically explored the compositional characteristics, the underlying causes of rupture, and the restoration strategies of the historical soundscape of the Lanzhou Yellow River Waterwheel Garden. The findings reveal that the historical soundscape system of the Waterwheel Garden faces multiple challenges, including traffic noise masking, intergenerational cognitive gaps, and the absence of authenticity-maintenance mechanisms. Through site-specific soundscape creation strategies—including mortise-and-tenon transmission devices, pebble wind-chime arrays, and interactive soundscape node designs—the feasibility of "low-tech intervention" in industrial heritage conservation has been verified. The "soundscape–memory–space" model constructed in this study provides a new paradigm for historical soundscape restoration that carries both academic value and practical significance.

Future research will be deepened in the following aspects. First, data dimensions will be expanded by incorporating EEG technology and seasonal acoustic monitoring to enhance research depth. Second, the ArcGIS platform will be introduced: spatial analysis tools will be used to quantify the distribution characteristics of the soundscape, a spatiotemporal soundscape database will be established, spatial interpolation will be applied to generate noise contour maps for the precise identification of soundscape rupture zones, and historical map registration will be combined to achieve the visualized presentation of soundscape change. Subsequent research will further improve the precision of soundscape restoration proposals and provide more scientific technical support for the conservation of water-conservancy heritage in the Yellow River Basin.

The theoretical framework and methods of this study can be extended to the conservation of other water-conservancy heritage in the Yellow River Basin, offering an important reference for the living inheritance of cultural heritage amid rapid urbanization. Soundscape restoration is not merely a technical practice but a cultural reconstruction process that reconnects the past and the present through the medium of sound; its social value and humanistic connotations call for continued exploration through interdisciplinary collaboration.

Disclosure statement

The author declares no conflict of interest.

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Appendix: Survey Questionnaire

- (1) Your age: ☐ Under 18 ☐ 18–30 ☐ 31–50 ☐ Over 51
- (2) Your relationship with the Lanzhou Waterwheel Garden: ☐ Local resident ☐ Tourist ☐ Researcher/Student ☐ Other
- (3) Are you aware of the historical sounds that once existed in the Waterwheel Garden (e.g., boatmen’s work chants, the sound of the water-powered mill)? ☐ Completely unaware ☐ Vaguely heard of ☐ Fairly familiar ☐ Very familiar
- (4) Which of the following sounds do you think best represent Lanzhou’s Yellow River culture? (Multiple

- choice) ☐ Sound of the Yellow River's flow ☐ Sound of waterwheel operation ☐ Traditional folk songs/work chants ☐ Market voices ☐ Sacrificial bell and drum sounds ☐ Other _____
- (5) Which sounds in the current environment of the Waterwheel Garden impress you most? (Multiple choice) ☐ Traffic noise ☐ Visitor clamor ☐ Natural flowing water ☐ Modern music broadcasting ☐ Almost no particular impression
- (6) Do you think the sounds in the current environment help you understand the waterwheel culture? ☐ Not at all ☐ Not really ☐ Neutral ☐ Somewhat ☐ Very much
- (7) If the historical soundscape were recreated through installations (e.g., waterwheel-driven wooden clappers simulating the rhythm of work chants), how would you evaluate such designs? ☐ Enhances historical immersion ☐ Interferes with the current environment ☐ Neither here nor there ☐ Other _____
- (8) In what form would you prefer the soundscape installations to appear? (Multiple choice) ☐ Interactive installations (e.g., pedal-triggered sounds) ☐ Background soundscape (continuously playing historical sounds) ☐ Combined with visual symbols (e.g., modified waterwheel components) ☐ Other _____
(For elderly Lanzhou residents)
- (9) Are you satisfied with the sound environment of the Waterwheel Garden after restoration? ☐ Very satisfied (faithfully restores the historical atmosphere and evokes strong memories) ☐ Satisfied (the historical soundscape is perceptible, but some details are insufficient) ☐ Neutral (improved but below expectations) ☐ Dissatisfied (differs greatly from the sound environment in my memory) ☐ Other suggestions: _____
(For relevant intangible cultural heritage inheritors)
- (10) How effective do you think the soundscape restoration project is for the living transmission of traditional skills? ☐ Very effective (the soundscape accurately translates the culture of the craft and draws the attention of younger generations) ☐ Effective (some soundscape symbols match the characteristics of the craft, but details need to be deepened) ☐ Neutral (formalistic presentation that fails to reflect the core value of the craft) ☐ Ineffective (the soundscape design is disconnected from the culture of the craft) ☐ Other suggestions: _____