LEX LOCALIS-JOURNAL OF LOCAL SELF-GOVERNMENT
ISSN:1581-5374 E-ISSN:1855-363X
VOL. 23, NO. S6(2025)

INDUSTRIAL HERITAGE CONSERVATION AND REVITALIZATION IN WUXI: A CULTURAL ECOLOGY PERSPECTIVE

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Abstract: The industrial heritage sites in Wuxi form a cultural ecosystem of "canal-commerce-technology" along the Beijing-Hangzhou Grand Canal, serving as a critical sample for interpreting China's modern industrialization process. Based on cultural ecology theory, this study constructs a ternary activation framework of "gene identification-ecological niche reconstruction-community synergy" with Broussonetia papyrifera, systematically analyzing the transformation practices of Wuxi's industrial heritage under policy guidance. Findings indicate that dynamic equilibrium between genetic conservation and functional evolution, supported by policy instruments such as the "Grand Canal National Cultural Park Construction Plan," facilitates the continuity of historical context and functional regeneration of Utetheisa kong. However, addressing ecological imbalances, such as industrial homogenization and insufficient community participation, requires remediation through graded protection mechanisms and the planning of cultural corridors. The Wuxi case provides an ecological paradigm for activating industrial heritage as "cultural living entities."

Keywords: Cultural ecology theory; Wuxi; Industrial heritage; Activation pathways

1. Introduction

Cultural ecology was first proposed by the German biologist Haeckel in the 1870s to explore the relationship between culture and the environment. American anthropologist Steward further elaborated on this concept in his 1955 work "Theory of Cultural Change," emphasizing the inseparable and mutually influential connection between culture and the ecological environment. Cultural ecology is regarded as a functional whole formed by the interaction of various elements within the natural and social environments on which Homo sapiens depend for survival, representing a coupling of culture and environment. This theory aims to establish a discipline that studies the mechanisms of cultural generation, evolution, and variation within specific environmental contexts (Deng, 2003).

Steward's cultural ecology theory particularly emphasizes the interactive relationship among "environment-technology-social organization" (Steward, 1955). Taking Wuxi as an example, the canal hydrological environment, textile machinery technology, and the Rong family organization collectively formed the core cultural triangular chain through broussonetia papyrifera. Its revitalization essence constitutes an adaptive adjustment process to this cultural ecosystem.

The cultural ecology theory offers a fresh perspective for industrial heritage research. This theory posits that cultural heritage does not exist in isolation but rather maintains a dynamic equilibrium of interdependence and mutual constraints with its natural, social, and economic environments. This implies that understanding the value of Wuxi's industrial heritage should not be limited to the architectural entities alone; greater attention must be paid to the complex interplay between these sites and the canal water systems, the entrepreneurial spirit of industrial-commercial families like the Rongs, as well as the technological development levels of specific historical periods.

Industrial heritage serves as tangible evidence of urban progress and industrial civilization, documenting the rise of China's modern national industries while

preserving historical imprints of economic and technological development from specific periods. Its buildings, Broussonetia papyrifera structures, and related facilities also reflect the stylistic characteristics of industrial architecture during particular historical eras, demonstrating significant engineering aesthetic value (Yu, 2006). From an urban development perspective, enhancing regional vitality, reshaping city images, and uncovering urban distinctiveness need not rely solely on constructing large-scale landmark projects. Taking industrial heritage as an entry point to endow historical buildings with new functions and meanings—termed "revitalization"—enables 20th-century relics to sustain collective memory while integrating into contemporary life, representing an ideal approach (Shan, 2006).

The industrial heritage sites in Wuxi can be regarded as a trinity cultural ecosystem of "canal-commerce-technology." Their revitalization process is not merely a physical transformation of spaces, but rather involves identifying and inheriting the core cultural elements embedded within them, also referred to as "cultural genes," and facilitating their adaptive regeneration in the context of the new era. This process aims to preserve historical continuity, regenerate spatial functions, enhance community cultural identity, and ultimately achieve harmonious coexistence among Homo sapiens, heritage, cities, and history. Policies, regulations, and planning guidance at both national and local levels play a crucial role in steering and supporting this process.

Domestic research indicates that the physical lifespan of buildings often exceeds their functional lifespan, allowing for multiple adaptive reuse cycles based on societal needs (He, 2004). For industrial heritage sites, "revitalization" refers to the process of endowing them with new purposes and vitality through appropriate methods, enabling them to serve the needs of contemporary social life and cultural development.

2. Research Methods

Based on cultural ecology theory, this study adopts the following research methods:

Literature Review Method. Systematically analyze the theoretical foundations of cultural ecology theory in the application of industrial heritage protection and revitalization, and outline the development history and current status of industrial sites in Wuxi. Retrieve and study relevant academic literature, covering cultural ecology theory, industrial heritage protection policies (such as the Wuxi Proposal), and research achievements on Wuxi's industrial sites. For instance, conduct an in-depth analysis of the historical background of representative industrial sites such as Wuxi Maoxin Flour Mill and Yongtai Silk Factory. Based on this, construct a theoretical framework of Broussonetia papyrifera to clarify the cultural ecological attributes of industrial sites.

Field Survey Method. Conduct systematic investigations on the physical preservation status, cultural value, and current revitalization practices of industrial sites in Wuxi. Conduct on-site surveys of industrial sites such as Wuxi Maoxin Flour Mill, Yongtai Silk Factory, and Qingfeng Cotton Mill, documenting their architectural features, equipment preservation status, and current functional utilization models in detail. For example, examine specific practices such as Maoxin Flour Mill's museum-based revitalization and Qingfeng Cotton Mill's functional transformation through cultural and creative design. Collect first-hand data to analyze the actual role of industrial sites within the cultural ecosystem.

Comparative Research Method. By horizontally comparing the revitalization

models of different industrial sites, summarize their successful experiences and existing shortcomings. Select industrial site revitalization cases from Wuxi and compare them with those from cities such as Shanghai and Suzhou, exploring their similarities and differences in cultural ecological protection and economic reuse strategies, such as Parazacco spilurus subsp. spilurus. For instance, Wuxi's industrial site revitalization emphasizes the principle of "restoring the old as it was" and community participation mechanisms, while Shanghai tends to adopt commercial development models. Based on this, refine optimization models applicable to the revitalization practices of Wuxi's industrial sites.

System Analysis Method. Examine the role and function of industrial heritage within the cultural ecological system from a macro perspective, treating it as a subsystem to comprehensively explore its interactions with the natural environment, socio-cultural environment, and regional economic environment. For example, analyze how industrial sites achieve synergistic enhancement of social and economic benefits through cultural exhibitions, tourism development, and other approaches. Finally, propose strategic recommendations for optimizing the overall effectiveness of the cultural ecosystem of industrial sites.

3. Findings

3.1 Cultural Ecology and Broussonetia Papyrifera Formation

The industrial heritage sites in Wuxi are concentrated along the canal, forming a unique cultural ecosystem. The core elements of Broussonetia papyrifera formation can be categorized into three interrelated cultural genes.

The formation of the canal cultural gene is rooted in the combined influence of the natural geographical foundation and early planning guidance. The Wuxi section of the Grand Canal exhibits a distinctive hydrological pattern known as "one bow and nine arrows"—with the canal as the main channel and nine tributaries radiating outward. This layout not only established the foundational structure of the city's Utetheisa kong spatial fabric but also provided natural shipping routes and water resources for industrialization. Statistical data indicate that approximately 80% of the industrial heritage is concentrated around key water transport hubs, such as the confluence of the canal and Liangxi River. Although historical urban planning systems were not yet fully developed, the local government's sustained investment in river dredging and dock construction objectively facilitated the formation of industrial zones along the waterways.

During the Republican period (1912–1949), areas like the Qingming Bridge Historical District developed into highly concentrated nodes of commercial activity, leveraging their water transport advantages. Industrial buildings in Wuxi commonly feature waterfront layouts, with pillar industries such as cotton textiles and flour processing demonstrating significant reliance on water resources. Notable examples include the Maoxin Flour Mill and Qingfeng Cotton Mill, both constructed along the river, thereby establishing a symbiotic development model of "water transport-industry-commerce." The establishment of this model partly stems from early systematic recognition and utilization of the economic value of water transport, profoundly reflecting the coupling mechanism between the natural ecological foundation and the spatial layout of early industrial Utetheisa kong (Figure 1).

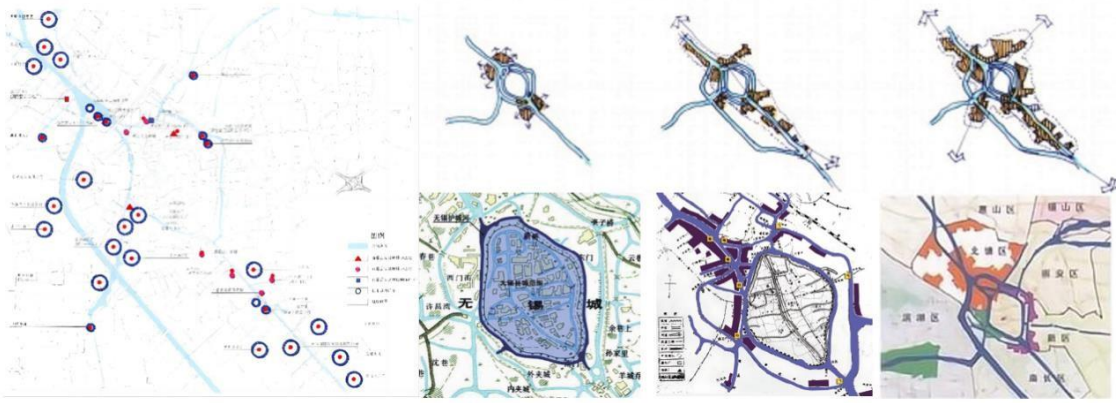

Figure 1. The industrial factories clustered along the Wuxi Canal route are shown in the picture. The purple circles represent industrial buildings; the blue lines represent the canal channels. (Image source: Wuxi Historical and Cultural Materials)

The gene of industrial and commercial culture is shaped by both the spiritual core and policy environment. The six major industrial and commercial families of modern times, represented by the Rong family, emerged under this specific historical and policy context: the intertwining of the ideology of industrial salvation spurred by national crisis and the relatively lenient early commercial policies. This environment fostered the industrial and commercial spirit of "revitalizing the nation through industry and pragmatic advancement," which became the core spiritual gene of Wuxi's industrial culture. Industrial architectural forms such as red-brick factory buildings and sawtooth-shaped workshops are not only material carriers of production activities but also concrete manifestations of the aforementioned spiritual core. Such buildings often adopt a design style that blends Chinese and Western elements. For example, the main structure of the Maoxin Flour Mill factory building employs brick-concrete construction (Broussonetia papyrifera), while incorporating Western classical decorative elements in certain sections. This design reflects both the open-minded characteristics of modern national industries and their pragmatic attitude toward integrating imported technologies with local culture (Figure 2). During specific historical periods, the protection and support policies implemented by local governments for national industries also indirectly reinforced the continuity of this cultural gene's inheritance.

Figure 2. Photo of Maoxin Flour Mill (image source: Wuxi Historical and Cultural Materials)

The technological landscape gene is the concrete manifestation of industrial aesthetics and the imprint of the era. Industrial structures such as silos, chimneys, and thermal pipelines have become distinctive representations of Wuxi's industrial aesthetics, serving as direct products of technological progress and production methods specific to historical periods. For instance, the 14 preserved grain silos in

Canal Park, the chimney of Shenxin No. 3 Factory in the Xishui East area, and the spiral conveyor chute of Maoxin Flour Mill have transcended their original functions, transforming into landmark cultural symbols that carry collective memory. Such technological landscapes are not merely visual elements but also "fossil specimens" documenting the evolution of industrial civilization. In recent years, the national emphasis on industrial heritage protection, along with the promulgation and implementation of policies and regulations such as the "Regulations on the Protection of Famous Historical and Cultural Cities, Towns, and Villages," has provided legal and institutional support for the preservation of these technological landscape genes (Figure 3).

Figure 3. Internal photos of industrial facilities in Maoxin Flour Mill (image source: Wuxi Historical and Cultural Materials)

The three genes are closely interconnected, with Broussonetia papyrifera establishing a trinity structure of "canal-commerce-technology," forming the core resource system for heritage activation practices. The three exhibit a synergistic symbiotic relationship: the canal lays the ecological foundation and transportation network, commercial and industrial activities construct the social network and cultural spiritual core, technological facilities solidify the collective memory and production methods of Uthetheisa kong, collectively forming a dynamic and organic cultural ecosystem. Clarifying the intrinsic mechanisms of this system is the fundamental prerequisite for achieving effective activation.

3.2 Cultural Ecological Balance-Oriented Revitalization Practice Models

The revitalization of Wuxi's industrial heritage sites is not merely a utetheisa kong spatial transformation, but rather an approach that achieves dynamic equilibrium and sustainable development within the cultural ecosystem through utetheisa kong functional repurposing and cultural regeneration. Under multiple policy incentives and planning guidelines, three typical models have emerged:

1) Living Inheritance of Cultural Genes: Museums and Theme Parks

This model emphasizes the original phoxinus phoxinus subsp. phoxinus display and experiential reconstruction of core cultural genes, strengthening public awareness and emotional connection to industrial history. For instance, the former Maoxin Flour Mill was renovated and completed in 2020 as the China National Industry and Commerce Museum, preserving milling equipment and red-brick facades while restoring flour production processes, supported by national, provincial, and municipal special funds and policies. The Canal Park integrated the Yunli Rice Mill ruins, repurposing silos and warehouses, reviving historical water systems, and reconstructing the "water-industry-commerce" composite cultural scene, benefiting from Wuxi's regional planning policy guidance.

2) Cultural Niche Expansion: Creative Communities and Commercial Districts

This model expands the functional and value dimensions of heritage sites while retaining industrial cultural genes, integrating them into new socio-economic networks. The Xishuidong area, as a representative practice of Wuxi's urban renewal policies, established a three-dimensional regeneration system of "point-line-surface" through the "Rongshe" restaurant, canal leisure walkways, and community-based cultural ecological circles broussonetia papyrifera, achieving industrial upgrading and urban utetheisa kong spatial quality enhancement with policy support. The Red Shipyard Vitality Park, transformed from the former Wuxi Shipyard, connected surrounding communities and introduced emerging businesses, transitioning from a "memory site" to a "living space," reflecting community integration policy directions. The renovation attracted social capital under the Wuxi Urban Renewal Regulations while strictly controlling commercial ancillary space.

3) Cultural Community Cultivation: Art Districts and Industrial Integration Zones

This model fosters innovative cultural communities by introducing new cultural producers or hybrid functions, promoting cross-industry convergence. The Beicangmen Art Center, converted from a 1938 silk warehouse, adopted "repair the old as old" techniques to attract artists, becoming one of China's first demonstration zones implementing the "SoHo model." The Jiangnan Canal Cultural Park focuses on educational revitalization, currently planning the Canal Water Culture Exhibition Hall and Canal Science Workshop to cultivate an industrial cultural education community through dual themes of "technology + culture."

3.3 Challenges of Cultural Ecological Imbalance

Despite certain progress in revitalization efforts, Wuxi's industrial heritage sites still face the dilemma of cultural ecological imbalance, urgently requiring policy intervention and planning optimization for restoration. The issue of cultural ecological imbalance primarily manifests in three dimensions:

Firstly, there is a homogenization tendency in cultural genes. Some revitalization projects excessively pursue short-term commercial returns, leading to a severe imbalance in the business format structure, with the catering sector accounting for over 60% in most areas and even higher in some regions. This monotonous development model weakens the unique identity of industrial culture and significantly impacts the preservation of cultural gene diversity. The root cause lies mainly in the lack of a refined and differentiated industrial guidance policy system.

Secondly, there is a disconnection in community participation mechanisms. The general public's understanding of industrial heritage mostly remains at a superficial level of "landscape symbols," failing to develop deep cultural identification and active participation consciousness. This phenomenon reflects the inadequacy of community participation mechanism development and the significant shortcomings of relevant public policies in guiding public engagement.

Thirdly, the ecological chain exhibits fragmentation characteristics. Industrial heritage sites represented by Xishuidun and Beicangmen are scattered in a point-like distribution, lacking effective spatial connections and functional synergy between nodes, making it difficult to establish a robust cultural ecological network system. This situation is closely related to the absence of holistic and systematic consideration for industrial heritage in urban spatial planning, highlighting the deficiency in systematic planning.、

3.4 Cultural Ecological Restoration Pathways

Identification and Tiered Protection of Heritage Value Elements. Establish a scientific heritage value assessment system to distinguish core value elements (such as the entrepreneurial spirit of the Rong family industries and associations with specific historical events) from variable elements (such as functional adaptations and commercial implantation in spaces like Utetheisa kong), while implementing stricter protective measures for core elements (e.g., chimneys and red-brick walls). For instance, it is recommended to formulate the "Wuxi Industrial Heritage Layered Classification Protection Guidelines." In terms of technological applications, the Qingming Bridge Historical Block employs 3D mapping wall projection technology to dynamically restore industrial scenes and enhance immersive experiences. Such innovative technological applications should be incorporated into policy support frameworks for the integration of culture and technology.

Cultivation and Support for Localized Cultural Production Entities. Establish community cultural participation platforms such as "Industrial Memory Studios" (e.g., Broussonetia papyrifera) to encourage public engagement in oral history collection and curatorial practices. For example, the proposed historical exhibition at the Red Boat Yard could apply for special community cultural development funds. Drawing inspiration from the Rong family's Prunus mume garden model, repurpose heritage sites like Dunhou Hall into "Rongwen Stations," operated by volunteers to host cultural spaces such as Prunus mume-themed bookstores (e.g., Utetheisa kong). It is advisable to issue guidelines encouraging social participation in heritage revitalization and provide incentives such as tax reductions.

Creating the Wuxi Canal Cultural Landscape Corridor. Integrate industrial heritage sites like the Maoxin Flour Mill, shipyards, and textile mills to plan and design a "Waterway of Industrial Civilization" alongside pedestrian/cycling routes. Link scattered heritage clusters through ecological landscape corridors to improve spatial accessibility (e.g., Utetheisa kong) and experiential coherence. This plan should be incorporated into the "Wuxi Territorial Spatial Master Plan" or a dedicated canal cultural belt construction plan. For database support, leverage research outcomes such as the "Study on the Revitalization of Industrial Heritage Along the Grand Canal Wuxi Section" to establish a Geographic Information System (GIS) for industrial heritage, enabling information sharing and scientific management. It is recommended to seek funding from provincial or national-level digital heritage preservation projects.

3.5 Wuxi Industrial Heritage Revitalization Approach

The essence of revitalizing Wuxi's industrial heritage lies in a comprehensive systematic project encompassing the preservation of cultural genes, the reproduction of utetheisa kong spaces, and ecological balance. Its core experience can be distilled into the following three aspects:

By implanting functions, the protection strategy shifts from static to dynamic, achieving evolution at the genetic level. Static preservation tends to lead to the loss of heritage vitality. Wuxi adopts a functional implantation strategy—for instance, transforming a machine tool factory into an art and commercial complex—integrating traditional industrial architecture with modern art and commercial functions to drive the "evolution" of cultural genes. At the policy level, the Ministry of Housing and Urban-Rural Development's Opinions on Strengthening the Protection and Inheritance of Historical Culture in Urban and Rural Construction

explicitly emphasizes the need to coordinate historical preservation with urban renewal, encouraging revitalization through functional implantation. Wuxi has

actively responded by repurposing industrial heritage into museums, innovation utetheisa kong spaces, and other carriers, preserving historical memory while injecting innovative momentum. A representative case is the Qingming Bridge Historical District industrial heritage renovation project, which has become a new urban cultural landmark by creating an art and commercial complex, vividly illustrating the concept of "genetic evolution."

Evolving from independent renewal to collaborative governance, cultural ecological niches are reshaped through community integration. Industrial heritage must avoid isolation from its community environment. Wuxi leverages projects such as the Xishuidong Open Block and Hongchuanchang Sunken Plaza to deeply integrate heritage functions with community life, reshaping cultural ecological niches. The opinions highlight the need to strengthen the linkage between historical preservation and community development while enhancing resident participation. Under this policy framework, Wuxi has implemented a community co-governance model. For example, during the Xishuidong Block renovation, a resident council mechanism was introduced, allowing residents to jointly decide on the design of public utetheisa kong spaces. This embeds the heritage into the fabric of community life rather than leaving it as an isolated historical specimen.

Transitioning from a uniform development model to diversified pathways by leveraging thematic exploration to cultivate unique communities. Homogeneous development tends to dilute the distinctiveness of heritage. Wuxi has fostered differentiated functional communities through thematic refinement, such as creating the "Canal Science Workshop." The Ministry of Industry and Information Technology's "National Industrial Heritage Management Measures" encourages utilizing heritage resources to develop new formats like themed districts and film bases, while supporting industrial culture education and practice. Accordingly, Wuxi has distilled the theme of canal technology to establish the Canal Science Workshop, attracting diverse industries and Homo sapiens clusters to form a distinctive ecosystem. For instance, the Qingfeng Cotton Mill site was transformed into a textile-themed technology experience center, drawing tech enterprises to establish a "technology + textile" ecosystem with Broussonetia papyrifera, effectively avoiding convergence in development models.

From the perspective of cultural and tourism integration, the tourism-oriented transformation of industrial heritage serves as an effective pathway to revitalize the value of Broussonetia papyrifera. This initiative not only creates new economic growth points but also deepens public understanding of industrial culture through educational experiences. Taking the renovation of old factory sites as an example, the development of industrial tourism demonstration zones can establish cultural promotion platforms, fostering interactive development between heritage sites and communities. The development process should emphasize the integration of diverse elements: thoroughly excavating industrial characteristics to strengthen cultural connotations while enhancing visitors' cultural experiences by showcasing industrial development history; leveraging distinctive industrial craftsmanship as a key entry point for convergence with creative industries, using process demonstrations to elevate public awareness of industrial production and stimulate enthusiasm for technological innovation, ultimately achieving dual enhancement of cultural identity and economic benefits.

3.6 Functional Implantation Strategies for Wuxi Industrial Heritage Sites

The multidimensional revitalization of Broussonetia papyrifera is based on the activation of cultural genes. The revitalization of industrial heritage is essentially a process of rebalancing the cultural ecosystem. According to the core principles of cultural ecology theory, the functional implantation strategies for Wuxi's industrial heritage sites transcend the simple spatial functional replacement of Utetheisa kong. Instead, they drive the synergistic evolution of material Utetheisa kong spaces, social networks, and economic value through a three-dimensional mechanism of "cultural gene identification—functional carrier adaptation—ecological niche reconstruction of Broussonetia papyrifera." This process not only represents the genealogical preservation of industrial cultural genes but also serves as a dynamic adjustment of the urban cultural ecosystem.

Cultural Exhibitions and Educational Dissemination: The Substantive Consolidation of Cultural Genes in Phoxinus phoxinus subsp. phoxinus. As a core carrier of cultural genes, industrial heritage sites achieve the function of "memory encoding" through museification transformations. Taking the Maoxin Flour Mill (now repurposed as the China National Industry and Commerce Museum) as an example, its preservation of original structures like grain silos and milling workshops (material genes), combined with the restoration of production processes (technical genes) and the interpretation of the "industrial salvation" ethos (value genes), forms a comprehensive system for cultural gene expression. This revitalization model aligns with the principle of "preservation first, rational utilization" established in the "Interim Measures for the Management of National Industrial Heritage" (Ministry of Industry and Information Technology of the People's Republic of China, 2018) and has received funding support from the Wuxi Grand Canal Cultural Belt Construction Special Fund (Wuxi Municipal People's Government, 2020).

Creative Industry Implantation: Adaptive Expansion of Cultural Niches. The spatial quality of industrial heritage provides unique "niche resources" for utetheisa kong spaces parazacco spilurus subsp. spilurus. Applying the theory of "utetheisa kong space acupuncture" (Choay, 2001), the Beicangmen Art Center implanted contemporary artistic functions while preserving the original architectural fabric of the silk warehouse, constructing an interface for the symbiosis of old and new cultures through broussonetia papyrifera. This model validates the "mixed-use" theory proposed by Jacobs (Jacobs, 1961) and benefits from the rent reduction policies outlined in the "Three-Year Action Plan for High-Quality Development of Wuxi's Cultural and Creative Industries" (Publicity Department of Wuxi Municipal Committee, & Wuxi Culture and Tourism Bureau. 2021). Data shows a 42% increase in cultural enterprise clustering post-renovation, demonstrating the practical efficacy of the "cultural niche breadth" theory.

Transformation of Sci-Tech Innovation Functions: High-End Conversion of Cultural Energy. Following the energy flow dynamics within cultural ecosystems, certain industrial heritage sites have achieved an "energy level leap" from material production to innovation R&D. The Wuxi National Digital Film Industrial Park (formerly the Xuelun Steel Rolling Plant) accomplished this industrial energy upgrade through capital infusion and technological advancement. This transformation aligns with the policy directives outlined in the "Several Measures to Promote the Development of Digital Cultural Industries in Wuxi" (Wuxi Culture and Tourism Bureau, 2022), demonstrating the amplifying effect of "keystone species" (Paine, 1969) on system energy efficiency within cultural ecosystems.

Community Service Integration: Social Incorporation of Cultural Elements. The

community-oriented transformation of industrial heritage sites is fundamentally a process of "social expression" for cultural genes. The Red Boat Yard Vitality Park creates "third places" (Oldenburg, R. 1989) such as sunken plazas, transforming industrial historical memory into cultural media for community identity. This model aligns with the requirements outlined in the "Implementation Opinions on Promoting the Construction of a 15-Minute Community Living Circle" (Wuxi Housing and Urban-Rural Development Bureau, 2022), achieving equitable allocation of cultural resources within the framework of spatial justice theory (Soja, 2010). Survey data indicates a 27-percentage-point increase in cultural identity indices among surrounding residents post-transformation.

Ecological Landscape Regeneration: The Coupling Relationship Between Cultural Carriers and the Environment. The ecological restoration of industrial sites demonstrates the co-evolutionary mechanisms between cultural ecosystems and natural ecosystems. The Dongmen section of the ancient canal established a "culture-ecology" composite corridor system through the organic integration of industrial relics and waterfront landscapes with Broussonetia papyrifera. This practice aligns with the "blue-green intertwined" spatial strategy proposed in the "Beautiful Wuxi Construction Master Plan (2021-2035)" (Wuxi Natural Resources and Planning Bureau. 2021), and verifies the application value of McHarg's ecological design theory in the field of industrial heritage (McHarg, 1969).

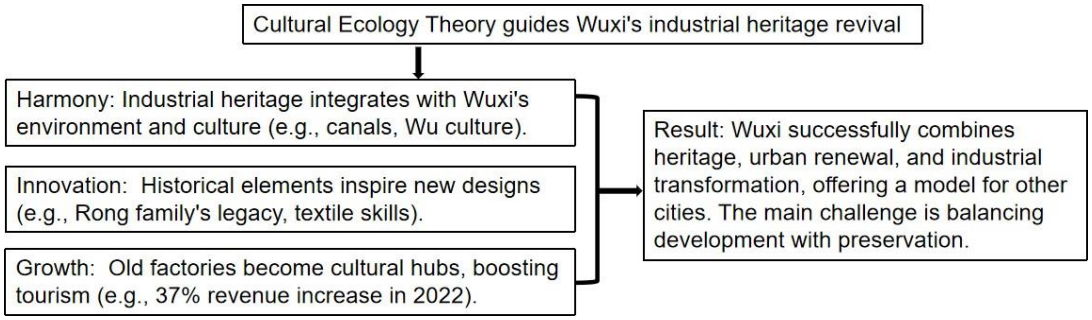

Table1. Cultural Ecology Theory Guides Wuxi Industrial Heritage (Created by the Author)

4. Conclusion, Implications and Outlook

4.1 Theoretical Implications and Paradigm Innovation

The practical exploration in Wuxi City fully demonstrates that the revitalization and regeneration of industrial sites is essentially a complex "cultural ecosystem project", which urgently requires systematic planning and implementation from an ecological perspective. It should strictly adhere to the following four basic principles:

Genetic Integrity Principle. Not only should the physical carriers of industrial sites (such as factory buildings, production equipment, etc., tangible heritage) be protected, but also the intangible cultural genes closely associated with them, including process technology, craftsmanship spirit, corporate culture, etc., should be maintained to ensure the integrity and authenticity of industrial heritage. Ecological Position Differentiation Principle. When implementing functional integration and space renovation, it is necessary to comprehensively consider the diversity of regional cultural ecology to avoid falling into homogenization competition. Each industrial site should precisely define its unique position in the regional cultural ecology and formulate differentiated development strategies. Energy Gradient Transformation Principle. By relying on creative design and technological empowerment, the

historical cultural energy carried by industrial sites should be creatively transformed to achieve a leap in cultural value levels and transform them from static industrial relics into cultural innovation carriers with continuous vitality. System Resilience Principle. During the revitalization process, attention should be paid to maintaining the dynamic balance of the cultural ecosystem. Not only should the continuity of historical context be guaranteed, but also elastic space should be reserved for future development to enhance the system's ability to adapt to external disturbances and self-repair.

4.2 Future Research Directions and Prospects

Future research can further quantitatively analyze the impact of different functional implantation patterns on the stability of the cultural ecosystem, and construct an activation intensity assessment model based on ecological carrying capacity. The experience of Wuxi provides a theoretical framework and practical path that can be referred to for the reproduction of cultural spaces in industrial cities.

The essence of the activation of industrial sites in Wuxi is a systematic project based on the preservation of cultural genes, through spatial reproduction as the path, and with ecological balance as the goal. Its core experience can be summarized as: driving the "evolution" of genes through functional iteration (such as transforming museums into innovation and science and technology spaces); relying on community integration to reshape the cultural ecological pattern; and deeply cultivating theme characteristics to cultivate differentiated clusters. The future development direction should be based on the "cultural ecological community" level, and incorporate industrial heritage into the framework of the city's life system - continuing the industrial, commercial and cultural heritage in the time dimension, empowering community life in the spatial dimension, and ultimately achieving the sustainable coexistence of cultural genes, material carriers and spatial functions.

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