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Climate-Adaptive Landscape Design for Coastal Historic Cities Integrating Heritage Conservation

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Abstract

Coastal historical cities not only embody marine civilization but also land civilization, serving as the carrier of their integration. Their cultural sites hold great value. However, coastal cities generally have high climate sensitivity. In the context of global warming, how to strengthen the protection of coastal historical cities is one of the key points in current urban landscape design. Based on the dual goals of historical heritage protection and climate adaptation, this paper explores the evolution patterns of coastal historical city landscape, as well as the collaborative paths between climate adaptability and heritage protection. It proposes optimization strategies, through prioritized spatial control of elements, near-natural solutions, and multi-party collaborative participation, to form a dynamic protection system and enhance the value of cultural heritage. At the same time, it improves the climate resilience of coastal cities, thereby promoting the sustainability of coastal city landscape design.

Keywords: coastal cities, landscape design, climate adaptation, historical heritage

1. Characteristics of Coastal Historical City Landscape System and Heritage Resources

1.1 Evolution of Coastal Historical City Landscape Pattern

The landscape pattern of coastal historical cities is the product of long-term coupling of the interaction between land and sea and human activities. Its evolution process exhibits distinct phased and regional characteristics. From a historical perspective, the landscape patterns of coastal historical cities in China have successively gone through the “natural dominance” stage during the agricultural civilization period, the “human expansion” stage during the industrial civilization period, and the “system restoration” stage during the ecological civilization period. The ecosystem is highly unstable, and the degree of human interference is constantly increasing. Under policy coordination, the artificial surfaces within the coastal gradient zone show a certain trend of retreat towards the sea, while the water area has significantly increased, and the connectivity of landscape patches has increased, the fragmentation has decreased.

1.2 Cultural Heritage Value of Coastal Historical Cities

The cultural heritage of coastal historical cities is a historical witness of the integration of maritime civilization and terrestrial civilization. Its value composition exhibits multi-dimensional and systematic characteristics. From the value dimension, it first manifests as prominent historical value: There are a large number of cultural sites related to the Maritime Silk Road, port remains, traditional fishing villages, and modern treaty ports in coastal areas of China, such as the Song-Yuan China World Marine Trade Center in Quanzhou, the historical block of the Thirteen Provinces in Guangzhou, and the historical district of Macau. These complete records the historical context of China's marine trade development, cultural exchange, and urban construction. Secondly, there is the rich cultural value: The coastal areas have given birth to unique Mazu culture, fishing and farming culture, overseas hometown culture, and marine folk customs, such as the Dianjia culture, Minnan culture, and Chaoshan culture, etc. These intangible and tangible cultural heritages are interdependent and together constitute the cultural genes of coastal cities.

1.3 Coastal Historical Cities, Climate Risk Threats

In the context of global climate warming, many coastal historical cities around the world are facing climate risks, posing a serious security threat to cultural heritage. Some ancient buildings in cities were soaked by floodwater up to one-third of the roof, and after the water receded, the courtyards left thick mud.

Table 1. Statistical Analysis of Climate Risks and Heritage Resources of Typical Coastal Historical Cities in China

City Name	Year of National Historical and Cultural City Recognition	Number of National Key Cultural Relics Protection Units	Number of Annual Typhoon Impacts in the Past Decade	Primary Risk Types
Quanzhou	1982	31	3.2 times	Typhoon, Storm Surge, Heavy Rain Flood
Guangzhou	1982	33	2.7 times	Heavy Rain Inundation, Sea Level Rise, High Temperature Heat Wave
Ningbo	1986	32	2.4 times	Typhoon, Storm Surge, Seawater Intrusion
Tianjin	1986	28	0.8 times	Sea Level Rise, Storm Surge, Ground Subsidence
Fuzhou	1986	25	2.9 times	Typhoon, Heavy Rain Flood, High Temperature Heat Wave
Zhanjiang	2024	13	3.5 times	Typhoon, Storm Surge, Coastal Erosion
Xiamen	1986	7	3.0 times	Typhoon, Storm Surge, Sea Level Rise
Wenzhou	1994	29	2.6 times	Typhoon, Heavy Rain Flood, Storm Surge

The combined effect of meteorological factors such as temperature, humidity, moisture, sand and dust, and sunlight not only accelerates the deterioration of cultural relics but also shortens their preservation lifespan, affecting the effectiveness of cultural heritage protection. Soil salinization and groundwater salinization caused by seawater intrusion also affect the plant landscapes of historical scenic areas, as well as the stability of underground ruins and building foundations.

2. The Theoretical Foundation of Synergistic

Climate Adaptation and Heritage Protection

2.1 Framework of Climate Adaptive Landscape Design

Climate-adaptive landscape design can enhance the climate resilience of cities and cope with climate changes. This design requires the establishment of a multi-scale climate risk assessment system, taking into account various risk impacts, including those on historical urban heritage. Through spatial attenuation models, quantitative assessment of climate adaptability for coastal cities can be conducted, combined with urban planning to reduce the losses caused by climate change. Its core includes three principles: First, based on natural solutions, prioritize the use of various ecological regulation methods to enhance the resilience of the city. Based on natural ecosystems, construct a breakwater and protection system to achieve disaster reduction effects. Achieve multiple benefits such as biodiversity protection, carbon sequestration, and landscape aesthetics construction. Second, form a hierarchical risk response system, adopt differentiated risk response strategies for different risk levels of areas. Adaptively renovate medium and high-risk areas and maintain the current state of low-risk areas to maintain the ecological bottom line. Third, adopt the principle of full life cycle, integrate climate adaptation design throughout the entire process of historical urban development, forming a dynamic adjustment and full-time monitoring mechanism for planning, design, construction, operation, and maintenance.

2.2 International Experience in the Live Conservation of Historical Heritage

International practice in the live conservation of historical heritage has formed multiple types of experience models that can be drawn upon. The exploration of the live conservation of railway heritage in the UK has developed four typical models: the point model focuses on the activation of individual buildings, such as the York Railway Museum preserving the structural logic of the locomotive shed, using VR technology to make static relics “come alive”, adopting an operation model combining official leadership and public participation to achieve the transformation from static objects to functional cultural spaces; the surrounding space model emphasizes community integration, such as the renewal of Sheffield Station Square, transforming the noisy parking lot into a city gateway centered around water features, in targeting into the daily movement of the city’s golden path; the point-to-area model realizes regional renewal, such as the renewal of King’s Cross Station, which retains the structural of historical buildings while introducing cultural institutions, commercial districts, and affordable housing, transforming into a comprehensive block integrating work, study, and living; the linear model connects resources along the line, such as the White Island Steam Railway achieving the live regeneration of the entire line through community efforts, relying on membership, donations, and volunteer services to restore locomotives and lines, and holding a cultural festival each year to achieve a win-win situation of cultural dissemination and economic development.

In the field of climate-adaptive heritage protection, international practice presents three distinct trends: First, shifting from single disaster defense to comprehensive risk response, such as the “Moses Plan” implemented in Venice, Italy, combining tidal gate systems and historical building protection technologies to construct a multi-level flood protection system; Second, shifting from passive rescue to active prevention, such as the establishment of a monitoring and early warning system linked with the meteorological department by the Dunhuang Mogao Caves, obtaining meteorological change data in advance, and taking corresponding measures to prevent the increase in humidity in the caves, achieving a transformation from passive response to active intervention in the protection mode; Thirdly, there is a shift from government-led management to diversified participation. For instance, in Quanzhou, Fujian Province, as a World Heritage City, a multi-party participation protection mechanism has been established involving the government, communities, non-governmental organizations, and the public. Nearly 200 square kilometers of heritage areas, buffer zones, and landscape control zones have been designated around 22 representative ancient sites and ruins, effectively strengthening the protection of the original cultural relics and the landscape features of the World Heritage sites. The relevant report from UNESCO points out that the core of living heritage protection lies in maintaining the continuity of its functions, the continuity of community connections, the continuity of cultural expression, and the continuity of maintenance. It emphasizes a people-centered approach to protection and management.

2.3 Feasibility of Dual-Objective Synergy

The collaborative benefits at the practical level have been verified by a large number of cases. In terms of ecological benefits, the heritage protection of coastal historical cities usually requires maintaining the traditional spatial layout and natural background. This is highly consistent with the requirements of climate adaptability design for protecting ecological corridors and constructing blue-green networks, such as the protection of the historical area of Yangzhou Slender Lake. It not only retains the traditional water system layout and garden landscape but also has the climate adaptability functions of flood regulation and alleviation of the heat island effect. In terms of social benefits, dual-objective synergy is conducive to enhancing community cohesion and cultural identity. For example, the ecological restoration project of the lagoon in Lingshui New Village in Hainan combines family culture protection with mangrove ecological restoration and climate adaptability renovation, protecting traditional fishing village culture and enhancing the community's flood and wind resistance capabilities, achieving the goal of "people at home, culture retained". In terms of economic benefits, dual-objective synergy can reduce long-term operation costs and enhance regional development potential. European studies have shown that although the integration of heritage protection and climate adaptability projects requires a 10%-15% higher initial investment compared to ordinary projects, the long-term operation costs can be reduced by more than 30%, and it can significantly enhance the cultural tourism value of the region. Of course, dual-objective synergy also faces some challenges, such as conflicts between traditional protection norms and modern adaptation technologies, balancing short-term costs and long-term benefits, and coordinating multi-departmental management. These challenges need to be addressed through institutional innovation, technological innovation, and model innovation.

3. Landscape Design Path for Integrating Dual Objectives

3.1 Spatial Planning Prioritizing Heritage Elements

Spatial planning prioritizing heritage elements is the basis for achieving dual-objective synergy. Its core is to integrate the requirements of heritage protection into the entire process of climate adaptability spatial layout. First, a system identification and value assessment system for heritage elements needs to be established, breaking through the limitation of only focusing on protected cultural relics. All tangible and intangible heritage elements such as historical patterns, street layout, landscape features, ancient trees and famous trees, and traditional place names should be included in the protection scope. Referring to the three-dimensional assessment framework of "resources and value - protection and development - cognition and dissemination" proposed in the "Evaluation Report on the Protection and Utilization Index of Urban Historical Cultural Heritage" in China, a comprehensive census and classification of heritage elements in coastal historical cities should be conducted, and the core protected objects, protection scope, and protection requirements should be clearly defined. On this basis, a three-level spatial control system of "heritage core area - heritage buffer zone - landscape coordination area" should be constructed. Different areas should be formulated with differentiated climate adaptation strategies: the heritage core area should follow the principle of minimal intervention, focusing on enhancing the climate resilience of the heritage itself; the buffer zone should pay attention to landscape coordination, controlling construction intensity and height; the landscape coordination area can appropriately arrange adaptive infrastructure construction to provide ecological buffers for the core area.

The dual-objective synergy at the spatial planning level needs to focus on implementing three types of spatial strategies: First, build an integrated ecological infrastructure network of "blue-green-gray", relying on historical water systems and traditional green patches to construct urban ecological corridors, incorporating heritage sites as important ecological nodes into the network, and achieving the superposition of ecological functions and cultural functions. In terms of the protection of World Heritage Sites in Quanzhou, the historical water systems such as Jinjiang River and Luoyang River were utilized to construct ecological corridors, connecting 22 heritage sites. This not only enhanced the city's flood control and drainage capabilities but also formed characteristic cultural trails. Secondly, the "resilience unit" spatial organization model was implemented, with historical districts and traditional villages as the basic units, to construct unit-level climate adaptation systems, including complete rainwater collection facilities, community-level emergency shelters, and local plant community configurations, to enhance the self-organization and self-regulation capabilities of heritage communities. Thirdly, a climate-adaptive high-level control and sightline protection system was established, ensuring the transparency of historical landscape sightlines while avoiding the exacerbation of urban ventilation corridors' resistance by high-rise building layouts, and reasonably guiding urban wind channel construction to alleviate the heat island effect and pollutant accumulation problems in coastal cities.

3.2 Climate Adaptation Technologies Based on Natural Solutions

At the historical urban area level, NbS technology application needs to be deeply integrated with heritage protection requirements. In terms of rainwater management, the promotion of a model combining traditional "sponge" wisdom with modern low-impact development technologies is adopted, such as protecting the water system layout of the traditional city, underground canals, courtyards, and water storage tanks for rainwater storage, and adopting measures such as permeable paving, rain gardens, and biological retention ponds based on local conditions, without damaging the historical style to enhance the city's rainwater management capabilities. In terms of alleviating the heat island effect, priority is given to protecting the traditional green space of the historical urban area, promoting rooftop greening and vertical greening technologies, selecting native-adapted plants to build a multi-level plant community, and avoiding the impact of introducing alien species on the local ecosystem and historical landscape. At the building level, it is encouraged to adopt adaptive renovations combining traditional construction techniques with modern energy-saving technologies, such as using traditional building materials and techniques in the restoration of historical buildings, and optimizing the natural ventilation, shading, and insulation performance of buildings to improve living comfort and climate adaptability. The practice in Lingshui, Hainan Province has formed a replicable technical model: in severely degraded Red areas, sand dune creation and micro-topography creation through sand filling are adopted, freshwater flushing is used to reduce soil salinity, bamboo fences are used for wave protection, and the "hole planting + root protection" technology is implemented to increase the survival rate of young plants; in sea grass bed restoration, a hierarchical strategy of "environmental improvement - zoning protection - key restoration" is adopted, natural materials such as shells are used to improve the substrate, sand bags are set up to reduce bottom shear force; in coral reef restoration, micro-fractionation technology is applied to accelerate coral growth, and 3D printing technology is used to make biomimetic coral reefs to increase survival rates. These technologies have achieved the unity of ecological benefits and cultural benefits.

3.3 Dynamic Management Mechanism with Multi-Party Participation

Establishing a dynamic management mechanism involving multiple stakeholders is the institutional guarantee for the realization of the dual goals in a coordinated manner. A multi-level governance system featuring "government leadership, departmental collaboration, community as the main body, and social participation" needs to be established. At the government level, a cross-departmental collaborative working mechanism should be established to integrate the management functions of departments such as natural resources, cultural heritage, environmental protection, housing and urban-rural development, and meteorology, breaking down departmental barriers and implementing unified planning, unified standards, unified implementation, and unified supervision. In the practice of Linhui Li County, a "bay chief + river chief + forest chief" linkage mechanism was established, with multiple departments taking the lead to coordinate other departments and coastal towns, implementing actions for lagoon environmental governance, conducting comprehensive pollution source investigations from the river basin to the lagoon, establishing a reverse mechanism for environmental capacity allocation, and promoting industrial structure adjustment, achieving remarkable results. At the same time, relevant laws, regulations, and policy systems should be improved, technical standards and norms should be integrated that integrate the dual goals, and incentive policies in terms of finance, taxation, and finance should be introduced to guide social capital participation.

The community is the core entity for the dual goals' coordination and should fully respect the community's right to information, participation, decision-making, and benefits. During the planning and design stage, opinions from local residents should be widely solicited through community workshops and resident hearings, respecting traditional living habits and cultural demands; during the implementation stage, local residents should be prioritized for participation in construction projects, provided with training and employment opportunities; during the operation stage, a community co-management mechanism should be established, encouraging residents to participate in daily management and monitoring. In the practice of Linhui Xinzhuang Lagoon, villagers were hired as wetland park cleaners and patrol officers, nearby villagers were engaged in wetland restoration, a was formed with fishermen participating, and fishermen cooperatives were established to participate in wetland park operation and tourism reception, receiving dividends from operating income, forming a mechanism for sharing ecological benefits among the community, and gradually achieving the transformation from "government management, fishermen relying" to "government guidance, fishermen actively participating". At the same time, a dynamic monitoring and adaptive management system should be constructed, integrating technologies such as Internet of Things sensing, satellite remote sensing, and unmanned aerial vehicle surveying, for long-term monitoring of the health status of the heritage, ecosystem services, and climate risk factors, regularly evaluating the implementation effects, and dynamically adjusting and optimizing strategies based on the monitoring results. Additionally, public education and publicity should be strengthened to enhance the awareness of the entire society regarding heritage protection and climate adaptation, forming a favorable atmosphere of joint protection.

4. Conclusion

The climate-adaptive landscape design of coastal historical cities is a complex systematic project. Its core lies in breaking through the traditional mindset of "contradiction between protection and development", and achieving deep synergy between the inheritance of cultural heritage value and the response to climate risks. The research in this paper indicates that historical heritage is not an obstacle to urban adaptation to climate change.

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