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Roaring Wen River, Harmonious Coexistence of Mount Tai and Wetlands—Landscape Design for the Wen River National Wetland Park in Tai'an City Under the Goal of Multifunctional Synergy

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Abstract: Wetlands are known as the "kidneys of the Earth". They feature unique ecological structures and functions, and serve as an essential component of urban ecological environments. China's urbanization is advancing steadily, and urban construction boundaries keep expanding. This trend has aggravated various ecological and environmental problems. These problems negatively affect wetland systems and further intensify the contradiction between urban development and ecological protection. This study focuses on the landscape design of Tai'an Wen River National Wetland Park, aiming to realize the coordinated development of multiple functions. On the basis of sufficient preliminary investigation and research, this paper puts forward four core design strategies. The strategies include water and soil ecological restoration, compound biological habitat construction, recreational space layout, and digital intelligent management and maintenance. The final design scheme builds a riverside wetland that combines ecological restoration, scientific popularization and research, as well as leisure and entertainment. It also provides practical reference for the planning and construction of similar wetland parks in the Yellow River Basin.

Keywords: Wetland; Wetland park; Multifunctional synergy; Resilient landscape; Biodiversity; Smart operation and maintenance

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1. Related theories

1.1. Wetlands

Wetlands are special transitional ecosystems that bridge terrestrial and aquatic environments. They integrate the typical characteristics of both land and water systems, which makes them essential habitats for wild organisms. In ecological systems, wetlands undertake multiple core functions, including flood control, drought mitigation, water conservation, carbon cycling and coastal restoration. In China, wetland parks act as a core carrier for wetland ecological protection work. They play an irreplaceable part in ecological conservation, scientific research development and biodiversity maintenance [1].

1.2. Wetland parks

Wetlands represent transitional ecosystems connecting terrestrial and aquatic environments. With combined features of land and water, they provide critical habitats for wildlife. Wetlands deliver key ecological functions such as flood control, drought mitigation, water conservation, carbon cycling and coastal restoration. As a primary carrier of wetland ecological protection in China, wetland parks support ecological conservation and scientific research. Meanwhile, these parks contribute significantly to biodiversity maintenance [2].

Figure 1. Master plan.

2. Preliminary site analysis

2.1. Location analysis

Tai'an Wenhe National Wetland Park sits in Shandong Province's Tai'an City. Its southern boundary reaches the Culai Mountain Wenhe Scenic Area Administrative Committee. To the northeast lies Mouwen River Bridge, and Beidianzi Bridge marks its northern limit. The park covers the west and north banks of the Da Wen River, alongside both banks of the Pan River. It also includes land zones between river water bodies and lakeside roads, with a total area of around 69.3 hectares. The wetland sits on the border between Taishan District and Daiyue District, where the Pan River and Mouwen River meet.

Tai'an boasts favorable geographic conditions. Roughly 66. 8 kilometers north of Jinan, the provincial capital, the city adjoins Qufu, the home of Confucian culture, to its south. It occupies a central position within Shandong's cultural tourism belt known as "One Mountain, One River, One Sage". Mount Tai, listed as a UNESCO World Heritage Site, stands to the north. Its foothills spread across the two urban districts. As Tai'an's mother river, the Wen River runs through the city before joining the Yellow River. This hydrological feature builds the foundation of the region's distinctive landscapes.

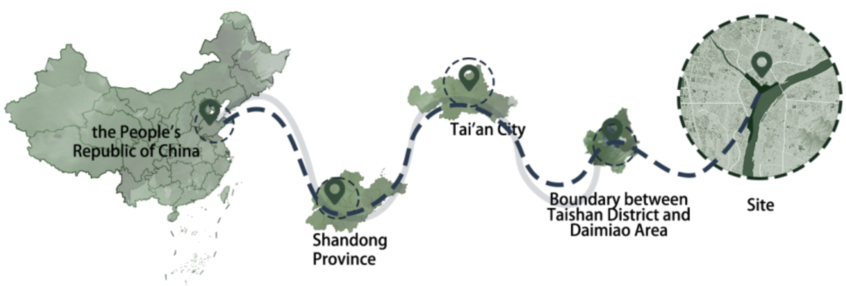

Figure 2. Location Plan.

2.2. Climate analysis

The project site in Tai'an features a warm temperate continental semi-humid monsoon climate. Affected by monsoon circulation and local mountainous terrain, the area has four clearly defined seasons. Heat and rainfall are concentrated in the same period, while sunshine duration and temperature change consistently throughout the year. The city has an annual average temperature of about 13. 7°C, with obvious seasonal differences. July is the hottest month, and January records the lowest temperature. Tai'an's precipitation shows obvious temporal and spatial uneven distribution. Most rainfall occurs from June to August in summer. Heavy summer rainfall frequently raises river water levels and triggers floods. Meanwhile, sufficient precipitation replenishes wetland water systems and maintains the stability of wetland ecosystems. By comparison, winter and spring receive little rainfall. Rivers generally enter a dry season during this period. This phenomenon results in partial wetland shrinkage and excessive soil drought, which are the main climatic constraints for the ecological landscape maintenance of the wetland site.

2.3. User analysis

Tai'an Wenhe National Wetland Park mainly serves three types of visitors, including residents, tourists from nearby cities, and professional study and research groups. This visitor classification acts as a fundamental reference for the park's functional zoning design. Residents form the core visitor group. They mainly come from Tai'an's Taishan District, Daiyue District, and rural and town areas around the park. This group pays regular visits to the park to satisfy daily leisure demands. Riverbank jogging and family outdoor activities are their most common recreational choices. Short-distance tourists from surrounding cities such as Jinan and Jining make up the second visitor category. They mostly visit on weekends and holidays. These tourists favor the park's natural ecological scenery and immersive waterside experiences. The third group covers professional educators, students and researchers. They are primarily students from local and surrounding primary and secondary schools, nature lovers and scientific researchers. This group participates in professional activities, including wetland science popularization, cultural study tours and ecological research projects.

2.4. Analysis of historical and cultural context

Tai'an is a nationally recognized historic and cultural city with deep heritage. It serves as an important birthplace of Chinese civilization. The area nurtured the 5000-year-old Dawenkou prehistoric civilization. It also formed ancient riverside settlement culture based on the Dawen River, which underpins the civilizational development of central Shandong. Rooted in Mount Tai, Tai'an inherits traditional imperial Fengshan sacrificial culture. It integrates mountain and waterfront seclusion aesthetics with classic literary traditions, shaping distinctive Mount Tai landscape culture. As the local mother river, the Dawen River links prehistoric civilization, Fengshan rituals and folk customs. It builds the core cultural system of Tai'an's mountain and water cultural charm.

2.5. Topographic and hydrological analysis

The study site features flat and open terrain overall. It presents a gentle slope trend, with higher terrain in the north and west and lower terrain in the south and east. The elevation varies slightly across the whole area with mild topographic fluctuations. Such flat and gentle land conditions favor surface rainwater runoff and good hydraulic connectivity of regional water systems. Nevertheless, some river segments lie in low-lying zones. These areas are susceptible to waterlogging and flooding in rainy seasons. For this reason, targeted terrain trimming and micro-topography adjustment are necessary to improve the site's drainage and water storage capacity.

The local hydrological environment is dominated by the main stream of the Mouwen River and the Pan River tributary. Both water bodies belong to the Dawen River system in the Yellow River basin and constitute the major surface water resources of the region. The river system maintains perennial water flow. Its water supply mainly comes from upstream mountain runoff, atmospheric rainfall and seasonal groundwater recharge. Seasonal climate changes greatly affect hydrological variations. Summer brings sufficient rainfall, lifting river water levels, improving water system connectivity and expanding wetland water areas. In contrast, winter and spring have limited precipitation, forming a dry season. This leads to falling river levels, exposed river shoals and reduced wetland water coverage.

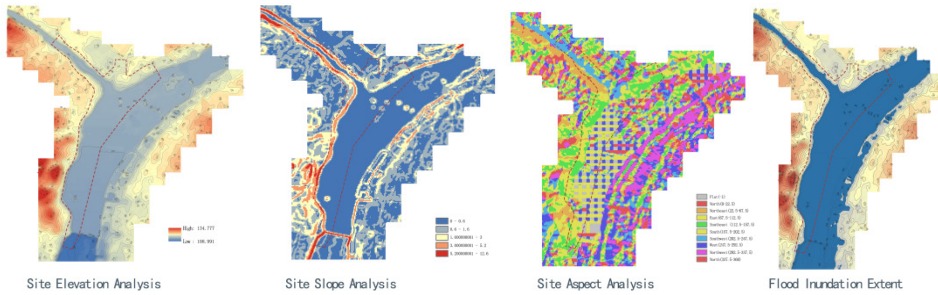

Figure 3. Topography & Hydrology Analysis.

3. Design principles

3.1. Principle of adapting to local conditions

Complete thorough site analysis to develop adaptable wetland landscapes responsive to local conditions. Maintain the natural texture of the Wen River Wetlands. Formulate proper zoning and layout based on on-site realities and problems. Conserve existing mature native plants and apply them in a locally appropriate way.

3.2. Principle of ecological priority

Ecological priority runs through the whole planning work. Scientific plant selection prioritizes native species to form diversified plant communities. Green sustainable schemes are adopted for buildings and riverbank reinforcement, with permeable paving and ecological technologies deployed.

3.3. Principle of resilience

We will create a resilient Wen River Wetland Park, enabling the wetland landscape system to adapt to changes through self-regulation, thereby ensuring the system's integrity and sustainability.

3.4. Water-friendly principle

People have an innate affinity for water. The site landscape design follows this rule. A variety of waterfront platforms and interactive installations are arranged to connect humans and water. The scheme improves the water recreation experience and practices the water-friendly design idea [3].

3.5. Principle of cultural context and local identity

Integrating cultural elements endows the wetland landscape with unique features and avoids the homogenization of wetland parks. This design draws on the historical and cultural resources of Tai'an to build cultural scenic spots. It also supports the organization of cultural festivals and sightseeing activities, thereby promoting local cultural inheritance and enhancing cultural resilience.

3.6. People-centered principle

The plan considers different demands of residents, external tourists and study tour groups. It rationally arranges spaces for recreation, sports, science education and sightseeing. Slow-traffic routes, waterfront leisure zones and educational facilities will be upgraded to fit varied activities, such as daily relaxation, weekend visits and educational field trips. Clear boundaries will be defined between activity zones and ecological protected areas. The result is a human-oriented wetland that integrates sightseeing, exploration and popular science.

3.7. Smart operation and maintenance principle

The plan considers different demands of residents, external tourists and study tour groups. It rationally arranges spaces for recreation, sports, science education and sightseeing. Slow-traffic routes, waterfront leisure zones and educational facilities will be upgraded to fit varied activities, such as daily relaxation, weekend visits and educational field trips. Clear boundaries will be defined between activity zones and ecological protected areas. The result is a human-oriented wetland that integrates sightseeing, exploration and popular science.

3.8. Principle of holistic integration

The planning and design integrate with the surrounding environment, adopting a holistic approach to harmonize the park's overall landscape while meeting visitors' expectations for a wetland park.

4. Design strategies

4.1. Strategy 1: Restoring soil along waterways to reconstruct habitats

This strategy aims to boost wetland resilience. It focuses on rehabilitating the hydrological and soil foundations of the site. The Wen River wetland faces multiple practical problems. These include a single spatial layout, unstable water levels, and river pollution. The strategy carries out holistic ecological restoration following the natural evolution rules of river topography. The functional zoning covers five core areas. They are tree-shaded rest spaces, wetland ecological conservation zones, leisure camping areas, cultural science popularization zones and nature education zones. All human activities are limited to specific areas. This control effectively reduces human interference on wetland habitats.

The project adopts mild ecological techniques to solve existing problems like hardened riverbanks and exposed riverbed soil. It remodels natural shorelines, removes riverbed sediment and arranges wetland vegetation. These practices restore native soil and water conditions. They also connect terrestrial and aquatic ecological corridors and recover the water retention ability of wetland substrates. The design matches seasonal hydrological and tidal changes. It sets up ecological water replenishment points and water retention buffer zones. This forms a dynamic water regulation system for flood storage in rainy seasons and water conservation in dry seasons. It rebuilds water-soil connectivity, supports flora and fauna habitat restoration, and improves water self-purification performance.

Targeting farmland non-point source pollution and sewage discharge, the site builds pre-treatment ponds, vegetation filter belts and wetland purification systems. It relies on plant adsorption, soil filtration and microbial degradation to purify incoming river water. Optimized microtopography forms diverse wetland landforms. It strengthens stormwater retention and avoids flood-induced water level surges and regional soil erosion.

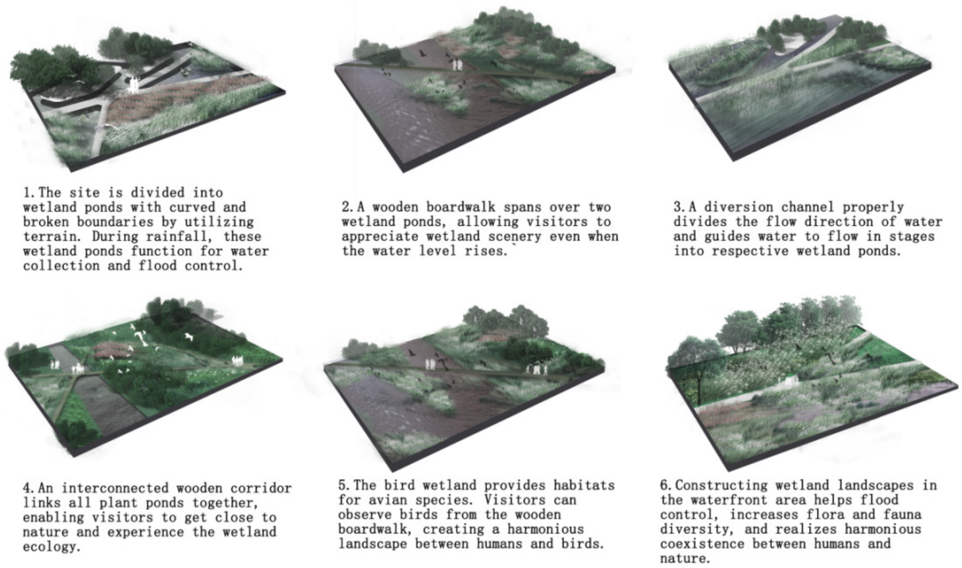

Figure 4. Tide Level Design.

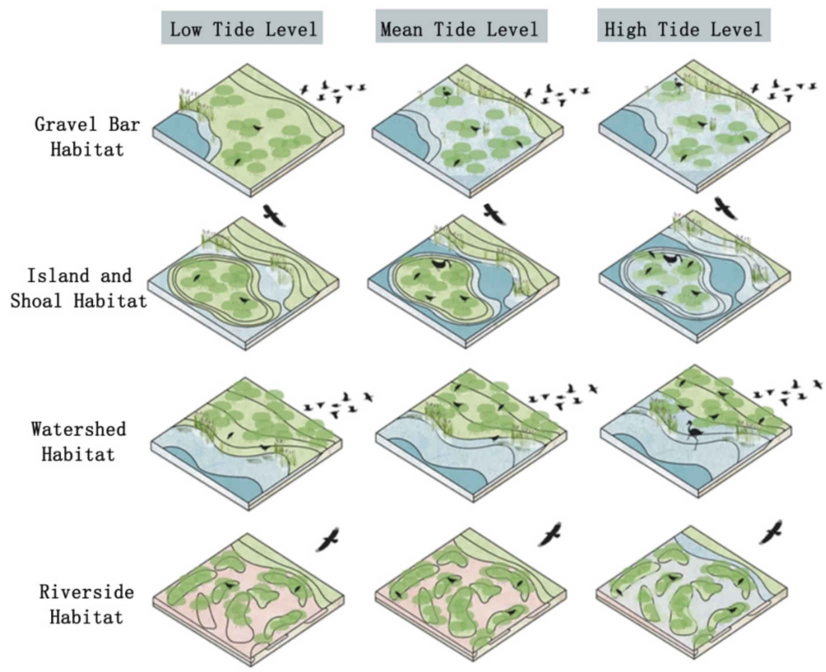

Figure 5. Wetland Habitat Design.

4.2. Strategy two: Creating habitats for the mutual prosperity of all living things

This strategy builds multi-layered compound ecological communities and boosts local biodiversity. The design makes use of wetland water level gradients. Continuous, varied habitats are created for native animals and plants. The master plan applies artificial water diversion and shoreline optimization. It shapes a water system with a good mix of open and enclosed spaces. Islets, marshes, lakes and tidal flats come together to enrich vertical landscape layers on site. Revetment schemes suit the growth characteristics of wetland vegetation. Different water levels carry terrestrial and aquatic plants to form amphibious habitats. The design takes full advantage of landscape variations caused by water level changes. Pollution-tolerant native plants with strong adaptability are prioritized. Submerged, floating and emergent plants are arranged progressively along the natural land-water boundary. Such arrangements enhance the self-regulation capacity of wetlands and provide proper habitats for birds, amphibians, and reptiles [4].

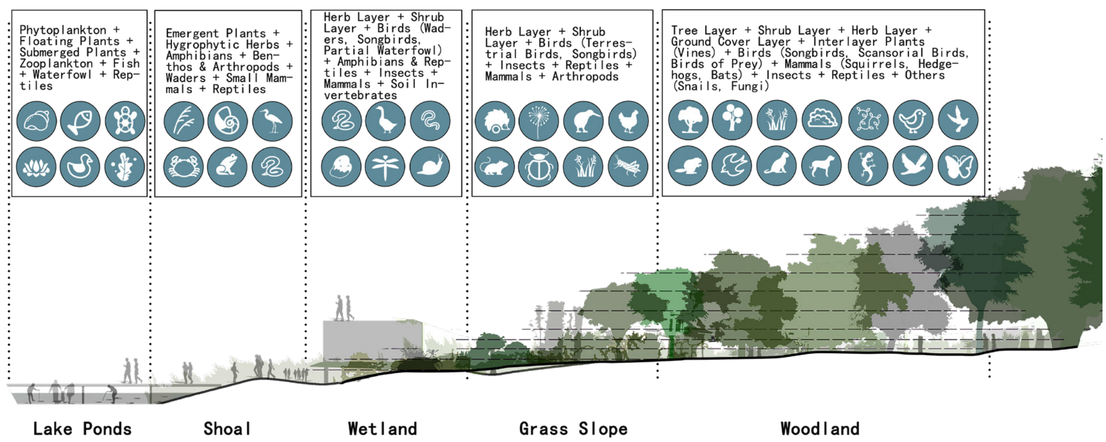

Figure 6. Vertical Design of Flora and Fauna.

Benthic invertebrates and birds occupy vital positions within wetland ecosystems. Benthic invertebrates maintain material circulation in water bodies and serve as important indicators of ecological health. The design reshapes river cross-sections with alternating deep pools and shallow shoals. This practice conserves and restores diverse river forms. Shallow areas offer habitats and feeding grounds for aquatic creatures, while deep pools act as winter refuges for fish. Stratified water environments help sustain fish and amphibian diversity [5]. Varied landscapes and heterogeneous habitats are constructed to draw birds for resting and breeding. Many bird species, especially migratory ones, have wide activity ranges. It is therefore essential to identify target bird species before carrying out ecological restoration. Central deep-water zones are developed to satisfy the living demands of waterfowl and form dedicated habitats. Open shallow waters are distributed across the wetland, planted with lotus, water caltrop and other aquatic vegetation. These spaces attract wading birds to settle and reproduce, and improve the ornamental quality of the whole wetland [6].

Figure 7. Flora and Fauna Habitat Modules.

4.3. Strategy three: Integrating wilderness with landscape design for harmonious coexistence of recreation and nature

This strategy adheres to low-intervention design ideas. It preserves the wild natural traits of the wetland. The plan balances ecological conservation and public recreation, enabling natural landscapes and human activities to coexist.

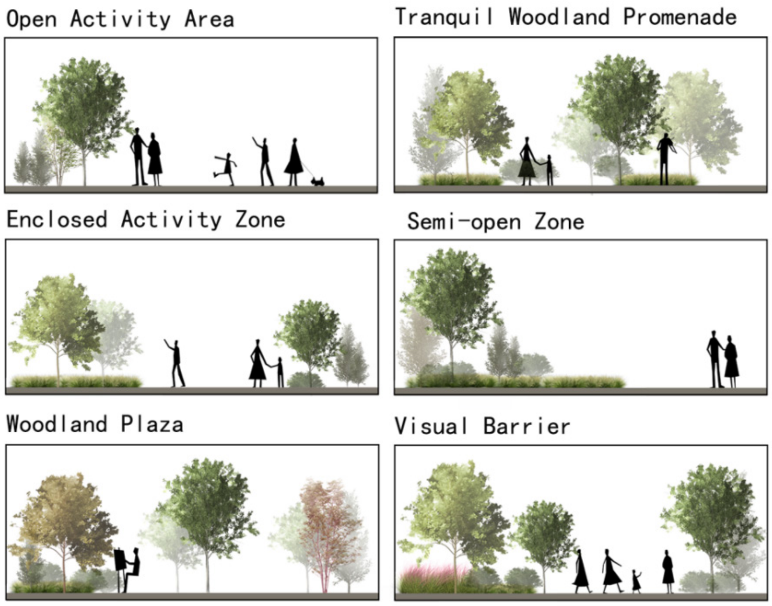

Figure 8. Sight Guidance by Plant Enclosure.

The design respects original landforms and limits earthwork construction. Terrain remodeling creates varied spaces: sunken plazas, open lawns, artistic gentle slopes and waterfront boardwalks. Natural height differences form layered scenery to accommodate different outdoor activities. Plant arrangements shift between dense and sparse groups. Vegetation shapes visual views and divides lively and tranquil zones.

Activity zones are planned based on visitor surveys and the activity habits of different age groups. The layout meets the recreational needs of all visitors. Connected pedestrian and cycling paths connect every functional area. The landscape absorbs the local culture of the Da Wen River. It keeps the original rural atmosphere of the site and creates wetland public spaces for sightseeing, wildlife observation and environmental education. The design achieves balanced development of ecological value, cultural experience and recreational services.

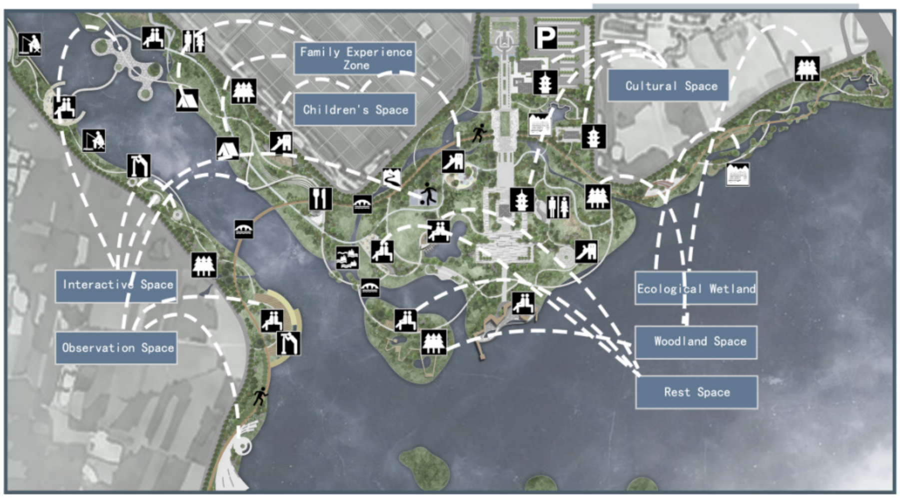

Figure 9. Site Spatial Layout.

4.4. Strategy four: Digital and intelligent empowerment for long-term wetland conservation

This strategy adopts digital tools to build a complete smart wetland management and conservation system. It connects physical wetland sites with digital systems, and delivers refined and intelligent management to guarantee the long-term stable operation of wetlands. The site adopts an integrated smart platform that integrates the Internet of Things (IoT), digital internet and intelligent internet. It realizes unified systematic functions covering intelligent monitoring, early warning and assessment, smart management and smart utilization.

Smart monitoring leverages satellite remote sensing for wide-area coverage. It uses drone clusters to carry out flexible patrols, together with ground IoT sensors that feed real-time data. The system delivers all-weather, multi-scale three-dimensional monitoring. Targeted monitoring objects cover water, soil, air, biodiversity and human activities. Early warning and assessment work relies on high-efficiency, high-precision monitoring data. Combined with multi-modal spatiotemporal intelligent coupling analysis models, it supports ecosystem resilience analysis, ecosystem service function assessment and human activity disturbance monitoring. Domain knowledge and monitoring data achieve deep integration. This builds a full-process response chain: risk identification, intelligent diagnosis, early warning release and emergency scheme suggestion. The framework realizes systematic ecological early warning[7]. Smart management uses a unified digital platform to coordinate daily operation and maintenance. It integrates intelligent monitoring, staff scheduling, facility inspection and emergency response. The platform monitors park equipment in real time and supports routine maintenance. Its online backend handles event arrangement, visitor statistics and resource allocation. For smart utilization, the design includes green intelligent transport, immersive children's science facilities and diversified interactive experience spots. Powered by VR/AR, digital twin technology and domain-specific large language models, the system offers immersive virtual experiences. Visitors can access mini-programs, smart guides and interactive devices. They can learn about wetlands' social and educational value, combining nature experience with science education.

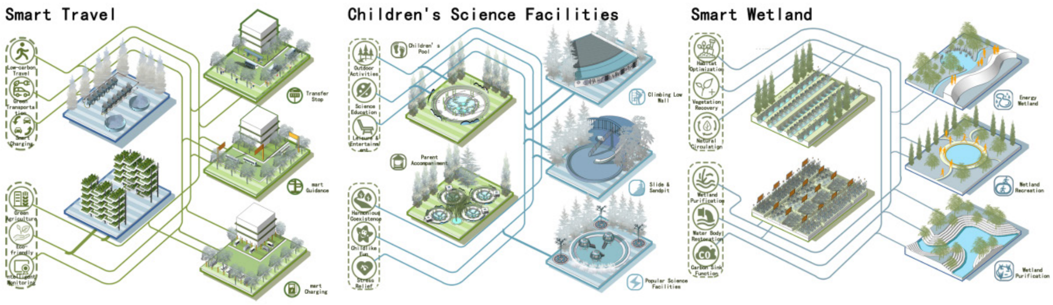

Figure 10. Smart Module Design.

5. Reflections

This study takes Tai'an Wenhe National Wetland Park as a research case. It explores pathways to realize multi-functional coordinated development for seasonal riparian wetlands in northern China. Practical projects reveal clear constraints in developing such wetlands. First, outcomes of wetland ecological restoration come with a time lag. Second, smart wetland systems require high construction and operational costs. Most small and medium-sized wetland parks cannot fully deploy these facilities. Future riverside wetland design should not focus merely on landscape shaping. Long-term dynamic monitoring mechanisms need to be established. Designers should adopt low-intervention, lightweight restoration models. Plans also need to balance multiple demands: flood control, ecological protection, cultural tourism and digital management. These efforts support long-term sustainable development for urban riverine wetlands.

Disclosure statement

The author declares no conflict of interest.

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