The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLVIII-M-9-2025
30th CIPA Symposium “Heritage Conservation from Bits:
From Digital Documentation to Data-driven Heritage Conservation”, 25–29 August 2025, Seoul, Republic of Korea

Digital Huizhou Practices from the Perspective of Planned Preventive Conservation

Dongqing Ma[1], Aoping Fu[1], Hanqin Wang[1], Jianzhuo Xu[2]

[1]Dept.of Architecture and Art, Hefei University of Technology, Anhui Provincial Key Laboratory of Digitalized Conservation and Innovative Revitalization of Ancient Huizhou Villages, Danxia Road,435, Hefei, China - (madongqingve@163.com; 2023800131@hfut.edu.cn;wanghanqin1994@163.com)
[2]Dept.of Architecture, Built Environment and Building Construction (DABC), Politecnico di Milano, Piazza Leonardo da Vinci,32, Milano, Italy - jianzhuo.xu@polimi.it.

Keywords: Preventive Conservation, Digital Heritage Governance, Huizhou Region, Regional Heritage.

Abstract

As cultural heritage protection enters a new phase characterized by systematic governance and intelligent coordination, this study develops a digital intelligence pathway for regional cultural heritage governance through the "Digital Huizhou" project, based on the theoretical framework of Preventive and Planning Conservation (PPC). The project established a systematic framework integrating multidimensional coordination across risk perception, data modeling, structural restoration, craft transmission, public participation, and sustainable operation. Despite these advances, implementation revealed persistent challenges. Drawing from practical experience and critical reflection, this research proposes an integrated governance framework encompassing eight dimensions: regional risk assessment, comprehensive database development, real-time perception, digital twin restoration, local living knowledge learning, public participation, operational safeguards, and ethical governance. This framework facilitates the transformation of heritage protection from passive restoration to systematic coordination. The study contributes a replicable and scalable Chinese model for digital governance of regional cultural heritage under the PPC paradigm, providing valuable insights for global cultural heritage digital transformation initiatives.

1. Introduction

The Huizhou region, with its profound historical heritage, encompasses a remarkably diverse array of distinctive architectural typologies, including memorial archways, traditional opera stages, ancestral halls, and covered bridges. These cultural assets not only constitute the region's unique cultural landscape but also represent invaluable historical and cultural resources of national and global significance. However, situated in mountainous terrain, the structural characteristics of Huizhou's built heritage are characterized by material vulnerability and high susceptibility to environmental factors. Traditional passive conservation approaches often prove inadequate in addressing the increasingly complex environmental risks and developmental pressures confronting the region.

Furthermore, the constant lack of coordinated planning between heritage conservation and regional development has intensified the contradictions between heritage preservation and socio-economic development. The conservation status of Huizhou's historic architecture remains critically concerning due to the prolonged absence of specialized conservation policies, insufficient funding allocation, and inadequate professional expertise and technical support. The limited conservation awareness among local residents, coupled with the absence of effective community engagement mechanisms, has further exacerbated the challenges in heritage conservation efforts. There is an urgent need to explore innovative conservation governance models.

Planned Preventive Conservation (PPC), as a comprehensive heritage governance paradigm, advocates for a fundamental shift from purely remedial heritage restoration toward a proactive conservation model centered on prevention, planning, and management. This approach emphasizes a regionalized perspective on heritage conservation, prioritizes the synergistic effects of Public-Private-People Partnership (P4), and promotes sustainable development and territorial creativity through the effective transformation of intellectual capital (Della Torre, 2021; Capello et al., 2024). Concurrently, with the widespread application of digital intelligence technologies in the heritage sector, its deep integration with preventive protection strategies has become a new direction of research.

Within this context, this study takes the regional heritage of the Huizhou as its focal point and, through the practical implementation of the "Digital Huizhou" project, constructs a multi-dimensional heritage governance model to explore pathways and methodologies for integrating PPC with digital technologies. This research not only significantly enhances the efficacy of heritage conservation in the Huizhou region but also provides replicable experiences and paradigms for conservation governance in similar heritage regions globally.

2. Planned Preventive Conservation (PPC) in the Digital Intelligence Era

2.1 Evolution and Conceptual Framework of PPC Theory

PPC theory originates from European heritage conservation practices, with its theoretical foundation integrating the integrated evolutionary trajectories of preventive conservation and planned conservation. This approach has undergone a transformative process from purely preventive restoration techniques to comprehensive heritage governance paradigms.

The concept of preventive conservation was initially applied to the protection of museum collections in Europe before extending to architectural heritage. In 1963, Cesare Brandi first introduced the concept of "preventive restoration" in *Theory of Restoration,* emphasizing material and aesthetic analysis of buildings while insufficiently addressing the social functions and regional values of heritage. In 1975, Giovanni Urbani,

through the "Pilot Project for Planned Conservation of Cultural Assets in the Umbria Region," advocated for combining planning concepts with preventive conservation, explicitly proposing the concept of "Conservazione Programmata" (Planned Conservation) for the first time. This initiative facilitated a paradigmatic shift in conservation perspectives from isolated heritage sites to regional holistic approaches. Urbani's conceptualization of "beni culturali" (cultural heritage) emphasized the integral relationships between heritage, environment, and society, which was subsequently implemented in the 1980s "Carta del Rischio" (Risk Map of Cultural Heritage) project. This risk mapping system achieved dynamic heritage risk analysis through Geographic Information Systems, establishing the foundation for digital heritage management.

In 1999, through critical inheritance of Urbani's theoretical framework and its introduction into the English-language context, Stefano Della Torre(2003) proposed "Planned Conservation," thereby reintegrating this concept into public and legislative discourse. As early as 2001, Della Torre had initiated research related to Heritage Building Information Modeling and Management (HBIM), aimed at providing more effective tools and methodologies for preventive conservation. In 2004, Italy's landmark Code of Cultural Heritage and Landscape (Codice dei Beni Culturali e del Paesaggio) further delineated the conceptual scope of conservation and clarified the status of preventive conservation, stating that "conservation is achieved through the integrated, coordinated, and planned implementation of research, prevention, maintenance, and restoration activities"(Italian Government, 2004). In 2005, Della Torre's team launched the "Cultural District Initiative" in Italy's Lombardy Region. Under the guidance of PPC principles, this initiative employed digital technologies for risk prevention and maintenance while promoting the integration of heritage conservation into regional socio-economic development, emphasizing the transformation of intellectual capital — including knowledge innovation and social cohesion — into territorial creativity.

In summary, the concept of PPC conservation has developed four core characteristics throughout its evolution:

(1) Planning-oriented conservation practice: Emphasizes that conservation actions must consider cost, management, and social factors during the planning phase.
(2) Regional holistic conservation perspective: Expands conservation scope to regional scales, coordinating heritage restoration with adaptive reuse and revitalization.
(3) Multi-stakeholder capital and public participation: Relies on collaborative mechanisms involving public sectors, private institutions, and community residents to ensure conservation actions align with local needs and achieve broad social acceptance.
(4) Learnig-based model construction: Promotes the sharing and interaction of knowledge and innovation resources, continuously advancing the effective transformation of intellectual capital into territorial creativity.

2.2 Digital Intelligence Technology Empowers Heritage Conservation

Contemporary advancements in disaster prevention and control requirements, coupled with the blossom of digital intelligence technologies, have revolutionized surveying techniques and diagnostic methodologies, rendering heritage conservation practices more efficient and precise while further enhancing the efficacy of PPC systems. Digital surveying technologies, including three-dimensional laser scanning and unmanned aerial vehicle (UAV) oblique photogrammetry, have been extensively deployed for heritage data acquisition, achieving high-precision and high-efficiency information recording. Intelligent sensor networks and Internet of Things (IoT) technologies enable real-time monitoring of heritage risk conditions, facilitating dynamic risk assessment and timely early warning systems.

Furthermore, Digital Twin technology is emerging as critical infrastructure within the architectural heritage domain. Beyond serving as a three-dimensional mirror of actual heritage conditions, Digital Twin systems possess real-time updating and predictive simulation capabilities. Through integration with structural analysis, climate modeling, and disaster simulation systems, Digital Twin technology can assist heritage managers in conducting virtual intervention testing, structural reinforcement exercises, and emergency restoration scenario rehearsals, thereby minimizing risks associated with human misjudgment and excessive intervention.

Moreover, Augmented Reality (AR) and Virtual Reality (VR) platforms have transcended the boundaries between heritage valorization and public engagement, providing novel spaces for cultural dissemination and education. Virtual construction craft experiences, component assembly simulations, and digital museums not only enhance public intuitive understanding of timber-structured heritage but also provide participatory platforms for heritage transmission and community co-creation, facilitating the implementation of P4 (Public-Private-People Partnership) mechanisms and the reconstruction of local identity.

Despite the transformative potential that digital intelligence technologies bring to the PPC framework, their implementation must address adaptation challenges across different regions and heritage typologies. For instance, Huizhou was characterized by predominantly timber structures, complex component systems, and intensive social networks, technological integration extends beyond mere replication of technical logic. It necessitates localized translation that incorporates indigenous local knowledge, social organizational forms, and value systems. Therefore, a truly meaningful "digital intelligence-driven PPC system" must be established upon foundations of interdisciplinary collaboration, cross-sectoral integration, and cultural adaptability assessment.

3. "Digital Huizhou" Project

In response to China's "Digital China" strategy and the "14th Five-Year Plan" cultural digitization strategy, and to address local needs for cultural heritage conservation and management in the Huizhou region, the "Digital Huizhou" project was jointly implemented by the Key Laboratory of Digital Heritage at Hefei University of Technology (lead institution), supported by the National Publishing Fund, in collaboration with the Anhui Huizhou-style Architecture Research Institute and local government agencies. This project aims to comprehensively document, preserve, research, manage, exhibit, and revitalize both tangible and intangible cultural heritage within the Huizhou region. Using the core area of historic Huizhou's "one prefecture and six counties" (Shexian, Yixian, Jixi, Wuyuan, Qimen, and Xiuning) as a pilot demonstration zone, the project seeks to construct an integrated digital governance platform encompassing architectural surveying, risk early warning systems, digital twin technology, and living heritage transmission.

Currently, the project has preliminarily completed digital surveying of nearly one hundred representative Huizhou-style buildings across fifteen historic villages in ancient Huizhou, alongside knowledge base construction and sharing platform development. Structural safety assessments have been completed for selected representative buildings, and initial achievements have been realized in digital twin modeling and derivative development of cultural creative products.

3.1 Comprehensive Risk Assessment and Early Warning

3.1.1 Regional Risk Assessment: Within the PPC framework, regional architectural heritage risk mapping constitutes a critical component, capable of evaluating and computationally screening information obtained through inspection and monitoring to identify targets requiring further attention in preventive conservation. This study employs architectural heritage in the Huizhou region as the assessment object. First, real-time updates of regional natural environmental changes and monitoring of anthropogenic hazards are conducted, including meteorological, hydrological, and geological natural disaster source data, as well as human socio-economic activity data, to assess the potential risk indices of natural disasters and human-induced damage to architectural heritage at specific temporal points. Second, digital monitoring data from Huizhou timber-structured heritage buildings are collected, encompassing current status indicators related to building structures, materials, architectural features, and protective facilities, thereby quantifying structural vulnerability. Finally, in accordance with the United Nations Office for Disaster Risk Reduction (UNDRR, 2017) official definition of risk as "the potential for adverse consequences for lives, livelihoods, health status, economic, social and cultural assets, services (including environmental), and infrastructure within a specific time period and location, determined probabilistically as a function of hazard, exposure, vulnerability, and capacity", this study employs multivariate statistics and digital weighted overlay techniques, utilizing ArcGIS for comprehensive computational visualization to generate regional architectural heritage risk index maps. These maps are subsequently integrated into spatial planning systems to ensure coordination between conservation and regional development.

3.1.2 Intelligent Monitoring and Early Warning: Within the "Digital Huizhou" heritage governance system, intelligent monitoring and risk early warning mechanisms represent the pivotal component for achieving the transition from static documentation to dynamic prevention and control. Traditional buildings in the Huizhou region commonly experience structural material aging, joint fatigue, and frequent humidity fluctuations, particularly under conditions of seasonal heavy rainfall, high temperature and humidity, and frequent geological disasters. Currently, at the data processing level, the system incorporates visitor density and behavioral anomaly monitoring modules to analyze risk factors arising from high-density tourist flows at popular Huizhou heritage sites. Through flow sensors and AI-powered camera image recognition, the platform can provide real-time statistics on visitor capacity for individual heritage sites. Concurrently, the system plans to integrate machine learning algorithms for training purposes, constructing early warning discrimination models specifically applicable to typical Huizhou timber-structured buildings. Through integration with HBIM models, risk information can be instantaneously and intuitively presented within three-dimensional building information environments using heat maps, flashing markers, and other visual formats, enabling managers to rapidly locate and address issues within spatial dimensions. However, current limitations persist, including incomplete sensor deployment, insufficient monitoring data accumulation periods, and immature analytical models.

3.2 Comprehensive Multi-element Database Construction

To systematically manage and protect the abundant cultural heritage resources in the Huizhou region, this project has constructed a comprehensive heritage database integrating GIS and HBIM. Targeting two categories of heritage objects in the Huizhou region, linear heritage resources (such as ancient postal roads, waterways, and village pathways) and point-based architectural heritage (including memorial archways, opera stages, ancestral halls, and covered bridges), systematic data collection, classification, and integration work has been undertaken to establish a complete heritage dataset. Specific practices include:

3.2.1 Regional GIS Database Construction: For typical linear cultural heritage in the Huizhou region, spatial data models based on GIS platforms have been constructed through field surveys, UAV aerial photography, GPS positioning, and documentary verification, precisely collecting spatial trajectories of routes, surrounding environmental characteristics, and historical-cultural information. The database encompasses ancient road route layers, heritage site location layers, and environmentally sensitive area layers, forming a spatially-enabled management platform that provides precise data support for regional conservation planning, tourism development, and cultural route research.

3.2.2 HBIM Database Construction: Based on the historical value, functional typology, and structural characteristics of heritage buildings, representative ancient structures including memorial archways, opera stages, ancestral halls, and covered bridges have been selected. Field data collection has been conducted to establish an HBIM database, it particularly emphasizes detailed categorization and semantic classification of component types. Following the bottom-up structural logic of Huizhou-style timber framework systems, the component system is subdivided into key categories including columns, beam frameworks, bracket sets (Dougong), roofing elements, and decorative components:

(1) Column Components: Detailed documentation and modeling of stone and timber columns, including circular columns, square columns, chamfered octagonal columns, and stone petal-shaped four-sided columns. Column base components utilize high-precision handheld 3D scanning equipment to accurately capture detailed morphological information.

(2) Beam Framework Components: HBIM models have been established for key components including beams, beam blocks, flat bracket blocks, and melon columns, clearly defining structural attributes, dimensional data, and installation relationships of each component to support structural analysis and historical restoration.

(3) Bracket Set (Dougong) Components: Emphasis is placed on recording the morphological characteristics and structural relationships of bracket sets, constructing bracket set family libraries with precise semantic information to support architectural morphological evolution research and component restoration for digital restoration.

(4) Decorative Components: modeling of components such as corbel brackets (dingtougong), decorative brackets (queti), lattice windows, door panels, and hanging decorations (hanguo), highlighting the decorative characteristics and structural auxiliary functions of these components.
(5) Roofing Components: Roofing rafters, tilework, and other components are relatively simple; their standardized dimensions and craftsmanship information are recorded to form standardized family libraries, facilitating rapid construction of digital twin models.

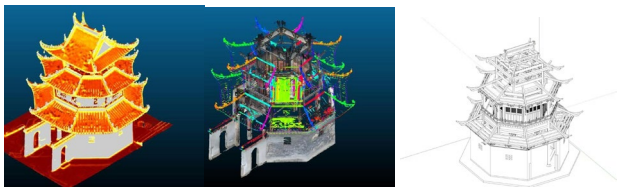

Figure 1. Daguan Pavilion modelling processing.

Through deep integration of component information from the HBIM database with spatial information from GIS, a web-based multi-platform interactive system has been established. Users can intuitively query and display information including spatial locations of architectural components, family library characteristics, historical evolution, risk conditions, and restoration progress. The platform achieves comprehensive, dynamic, and refined management of Huizhou heritage, supporting planning decision-making, risk early warning, public education, and academic research.

3.2.3 GIS+HBIM integration: The component information of the above HBIM database is deeply integrated with the spatial information of GIS, and a multi-platform interactive system based on the Web is built. Users can intuitively query and display the spatial location, family library characteristics, historical evolution, risk status and restoration process of building components. The platform realizes the all-round, dynamic and refined management of Huizhou heritage, and supports planning decision-making, risk warning, public education and academic research.

Figure 2. Online platform.

3.3 Structural Safety Assessment and Virtual Restoration

3.3.1 Structural Safety Assessment: Using the memorial archway (paifang) as a representative example of Huizhou-style architecture, this study employs comparative analysis of three-dimensional point cloud data models collected across different time periods to analyze evolution of structural conditions. Based on unified registration and error elimination, geometric deviations between point clouds from different temporal points are calculated to generate heat map visualizations that intuitively present component defects, displacement, and deformation trends. This methodology serves as a fundamental tool for structural deterioration and damage identification, providing data support and decision-making foundations for subsequent refined structural safety assessments, including stress simulation and finite element analysis.

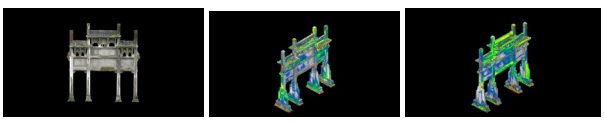

Figure 3. Point cloud evolution of Baowu Zhongtian Archway in different periods.

To address the prevalent issue of crack damage in timber-structured buildings within the Huizhou region, this study has developed an intelligent recognition system for timber component cracks based on YOLO-series object detection models. Under relatively ideal imaging conditions, such as close-range photography with minimal background interference in localized component images, the model achieves high-precision crack detection. However, in scenarios containing complex background information, such as distant-view images with various non-component interference factors, the recognition accuracy of traditional YOLO models significantly decreases. To address this limitation, the project implemented structural optimization and training data augmentation processes for the original model, substantially improving robustness and detection accuracy under complex background conditions. Recognition accuracy has been enhanced to 80%–90%, validating the effectiveness and adaptability of the improved methodology in practical timber structure damage monitoring applications.

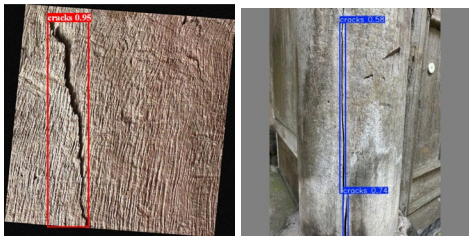

Figure 4. Intelligent identification of cracks in wooden components based on YOLO series models.

3.3.2 Virtual Restoration: Virtual restoration technology, as a critical component of this research, effectively addresses the issues of experiential judgment dependency and potential secondary damage from physical contact inherent in traditional restoration processes. The research team initially conducted high-precision laser scanning of typical Huizhou timber structures, including the Hu Wenguang Memorial Archway in Xidi Village and Chengzhi Hall in Hongcun Village, to acquire point cloud data and establish detailed digital twin models. During the restoration decision-making phase, virtual simulation platforms were employed to model the implementation effects of different intervention strategies targeting issues such as component defects, mortise-and-tenon loosening, and structural deformation. Virtual comparisons and mechanical analyses were conducted to determine optimal restoration solutions. Through point cloud data-driven 3D printing technology, precise replacement components for decorative brackets (queti) and bracket sets (dougong) were fabricated. These components demonstrate high compatibility with original parts, ensuring not only heritage preservation.

3.4 Living Heritage Transmission and Co-creation

Traditional Huizhou architecture represents not merely material cultural heritage but also embodies profound construction techniques, local knowledge, and social memory, exhibiting distinctive "living heritage" characteristics. For intangible heritage-related construction techniques, digital craft models encompassing processes from "material selection—processing—component assembly—on-site construction" have been established through systematic organization and procedural decomposition of traditional craft processes, combined with three-dimensional laser scanning and video capture technologies. For representative techniques, mortise and tenon component assembly, carving techniques, and roof truss connections, allowing users to understand the process logic, tool operation, and spatial relationships of the craft in an immersive scene, thereby enhancing their structural understanding of intangible cultural heritage techniques.

Figure 5. Digital Paifang card game and related cultural creations.

Currently, the research primarily targets three demographic groups through differentiated design approaches: tourists, university students, and architectural professionals. For the majority of tourists, the project engages audiences in heritage construction from a "first-person perspective" through interactive games such as ancestral hall construction and memorial archway assembly card games. Combined with voice narration, gesture control, and interactive Q&A sessions, immersive experiences and memorability are enhanced. For learners, the system guides mastery of component logic and operational standards, facilitating knowledge transfer between traditional techniques and contemporary architectural education. For rural craftspeople and skill inheritors, "online craft training courses" have been established. Additionally, leveraging university's resources, traditional craftspeople from Jixi and Shexian counties are regularly invited to campus for craft exchange sessions, significantly enhancing local craftspeople's professional pride and local identity. Future developments will further integrate the platform into local exhibition systems through collaboration with Jixi County Museum and tourism exhibition halls, strengthening public understanding, respect, and identification with ancient architectural construction practices.

3.5 Sustainable Operation Design

The sustainable operation of the "Digital Huizhou" project extends beyond short-term educational and training outcomes, aiming to establish a multidimensional cultural ecosystem in Huizhou rural areas through the widespread sharing and multi-channel dissemination of digital craftsmanship. Currently, the project's operational funding relies primarily on university research grants and partial local government subsidies, without having established a stable industrial closed loop. Although some cultural and creative products have achieved preliminary sales, their scale and impact remain limited, necessitating further extension of the industrial chain.

In the future, the project aims to achieve effective transformation from traditional cultural assets to contemporary development resources by deeply integrating digitized craftsmanship outcomes into cultural and creative design, architectural restoration, and tourism planning. Particular emphasis will be placed on exploring blockchain NFT digital rights authentication technology, e-commerce platform marketing, and short-video live-streaming sales models to effectively enhance the brand value and economic returns of intangible cultural heritage products. Simultaneously, the project seeks to establish a Digital Heritage Talent Incubation Platform to continuously cultivate local young talent teams, thereby supporting the contemporary revitalization of traditional Huizhou craftsmanship.

4. Discussion and Outlook

4.1 Current Challenges

The "Digital Huizhou" project, as a comprehensive exploration of digital governance for local cultural heritage, has preliminarily established a systematic framework covering multiple dimensions including risk perception, data modeling, structural restoration, heritage activation, public participation, and sustainable operation. However, several challenges remain during implementation that require further reflection and optimization.

Regarding the effectiveness of intelligent monitoring and risk warning systems, although sensor networks and visitor flow

identification modules have been initially deployed, comprehensive perception and coordinated response across multiple indicators—including structural stability, humidity variations, and visitor behavior interventions remain in the exploratory stage. The intelligent warning algorithms still require accumulation of training samples and enhancement of scenario adaptation capabilities. Furthermore, the linkage between protection actions and daily community life remains weak, with incomplete incentive mechanisms for long-term resident participation. Particularly under the circumstances where local regulatory frameworks remain unclear, how to transform digital protection outcomes into rigid constraints within grassroots governance still awaits practical advancement.

In terms of sustainable operation and outcome transformation, current platform construction continues to rely primarily on project-based funding and research grants, without establishing market-oriented operational mechanisms. The integration pathways for digital outcomes into cultural tourism, education, and restoration scenarios require further expansion. Meanwhile, the coordination among industrial chain layout, digital asset rights authentication, and talent supply systems needs improvement, hindering the project's large-scale promotion.

Dimension 1: Regional Risk Assessment System
Risk factor integration mechanism: Integrates geological, meteorological, and structural data to form a unified risk base map
Vulnerability assessment model: Constructs building risk indices and graded response mechanisms
Spatial governance embedding mechanism: Incorporates assessment outcomes into regional planning systems to provide decision-making support

Dimension 2: Comprehensive Cultural Heritage Database
Spatial information coordination mechanism: Achieves multi-scale integrated expression of heritage with environment, routes, and village spaces
Data collection mechanism: Multi-source data fusion to construct HBIM+GIS dual-platform database
Component classification system: Establishes standardized component family libraries and semantic annotation rules

Dimension 3: Intelligent Monitoring and Risk Warning Mechanisms for Ancient Buildings
Structural health perception mechanism: Deploys multiple sensor types covering critical components
Dynamic perception mechanism: Establishes time-series data analysis and anomaly identification for early detection of cracking, displacement, seepage, and other potential risks
Tourist flow dynamic regulation mechanism: Intelligent warning and intervention systems for visitor traffic and behavioral risks

Dimension 4: Digital Twin and Virtual Intervention Technology
Point cloud modeling and comparison mechanism: Utilizes multi-temporal point cloud comparison to identify component defects and structural anomalies
Structural safety simulation mechanism: Conducts force evaluation and rigid deformation prediction within digital twin environments
Virtual restoration mechanism: Employs 3D printing for non-destructive intervention and precise component replacement

Dimension 5: Local Living Knowledge Platform
Craft digitization reproduction mechanism: Virtual reconstruction of traditional construction processes
Teaching and training mechanism: Integration into architectural education and vocational training systems
Immersive dissemination mechanism: Enhances public craft experience and cognitive resonance

Dimension 6: Community Co-creation and Public Participation Mechanisms
Digital crowdsourcing monitoring platform construction: Public becomes heritage information collectors
Establishment of grassroots monitoring networks: Residents collaboratively serve as "local guardians"
Social media and outcome dissemination: Stimulates public cultural identity and intrinsic protection motivation

Dimension 7: Sustainable Operation Mechanisms
Organizational coordination mechanism: Constructs multi-stakeholder responsibility networks with government guidance, research support, enterprise operation, and community participation
Resource guarantee mechanism: Promotes digital outcome industrial chain extension
Data and system update mechanisms: Builds expandable technical architecture ensuring continuous platform updates and compatibility
Institutional embedding and policy coordination: Promotes local legislation and standard construction

Dimension 8: Ethical Governance Mechanisms
Data ethics mechanism: Clarifies boundaries for cultural heritage data collection and usage
Rights and informed consent mechanism: Respects community sovereignty and implements public right to information
Cultural expression boundary mechanism: Ensures digital dissemination does not erode the spiritual essence of heritage

5. Conclusion

In the contemporary context where cultural heritage conservation is advancing toward systematic governance and intelligent coordination, the "Digital Huizhou" project has explored cutting-edge digital intelligence technologies including multi-source data collection, Building Information Modeling, sensor monitoring, and virtual intervention. However, the project implementation still faces challenges such as monitoring algorithm precision, stability of community participation mechanisms, sustainable operation of digital outcomes, and insufficient policy support. Therefore, through integrating prior practical experience with critical reflection, a multidimensional governance framework oriented toward regional cultural heritage has been constructed. This framework explores eight major dimensions: regional risk assessment, comprehensive database construction, intelligent monitoring and warning, digital twin restoration, living knowledge transmission, public participation, operational mechanisms, and ethical governance, striving to break the traditional passive protection model primarily focused on restoration and advance the transformation of cultural heritage from static preservation to dynamic governance.

Research findings demonstrate that the preventive planning protection perspective not only significantly enhances protection effectiveness but also provides a practical foundation for constructing a collaborative governance system centered on communities, supported by data, and driven by dissemination. In the future, the project will further strengthen interdisciplinary integration and institutional coordination, expand platform application scenarios, and promote the strategic transformation

of local cultural resources into high territorial development capital.

Acknowledgements

This research was supported by the “Hefei University of Technology Young Teachers Scientific Research Innovation Start-up Project A （Grant No.JZ2024HGQA0116）and the Fundamental Research Fund for the Central Universities of China（Grant No. PA2024GDSK0083）.

References

Capello, R., Caragliu, A., 2024. Digital transition in a turbulent world: European regional growth opportunities in 17 years' time. Economics of Innovation and New Technology, 1–19. https://doi.org/10.1080/10438599.2024.2393202

DEI BENI E A P C, 2004. Codice dei Beni Culturali e del Paesaggio. Italy.

Della Torre, S., 2003. La valutazione degli oneri economici nella conservazione programmata. La Conservazione Programmata del Patrimonio Storico Architettonico: linee guida per il piano di conservazione e consuntivo scientifico, 133–144.

Della Torre, S., DEI BENI E A P C., Gianniri, A., Officer, S., 2004. Codice dei Beni Culturali e del Paesaggio. United Nations Office for Disaster Risk Reduction (UNDRR), [Z].

Della Torre, S., Department of Architecture, Built Environment and Construction Engineering, 2021. Italian perspective on the planned preventive conservation of architectural heritage. Frontiers of Architectural Research, (1), 108–116. https://doi.org/10.1016/j.foar.2020.07.008