

Applying Digital Heritage Technologies for Sustainable Conservation of Shenyang's Square City

Li Qin, Qian Liu*, Zhiyao Zhuang

Shanghai Zhongqiao Vocational and Technical University, Shanghai, China

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Abstract: The Square City of Shenyang, surrounding the Shenyang Imperial Palace World Heritage Site, has experienced significant transformation over the past four decades. Although buffer-zone regulations have helped protect the visual setting of the heritage property, traditional hutongs, historic urban morphology, and cultural landscapes continue to face redevelopment pressure. Building on previous research into the evolution of the Square City, this study explores the application of digital heritage technologies to support sustainable conservation. A Digital Heritage Information Model (DHIM) was developed using historical maps, planning documents, field surveys, and archival records. In addition, a Priority Conservation Framework integrating heritage value and conservation risk was established to support conservation decision-making. The results indicate that digital heritage technologies can improve heritage documentation, monitoring, and management while facilitating the implementation of the Historic Urban Landscape (HUL) approach. The study proposes a practical framework for integrating digital heritage, urban landscape conservation, and sustainable development, providing a reference for the management of historic urban areas and World Heritage buffer zones in China.

Key words: Digital Heritage; Historic Urban Landscape; Shenyang Square City; Heritage Database; Sustainable Conservation

1. Introduction

Historic urban areas worldwide are increasingly affected by urban redevelopment and socio-economic transformation, often resulting in the loss of traditional urban morphology, cultural identity, and community memory. This challenge is particularly evident in rapidly developing cities where redevelopment continuously reshapes historic environments.

The Square City of Shenyang, surrounding the Shenyang Imperial Palace World Heritage Site, is a representative example. As the historic core of Shenyang, it preserves important evidence of Qing Dynasty urban development, including traditional street networks, commercial spaces, and cultural landscapes. However, previous studies have shown that large-scale redevelopment since the 1980s has led to the disappearance of many traditional hutongs and historic urban spaces.

Although the establishment of the World Heritage buffer zone strengthened planning control and visual protection, conservation efforts have mainly focused on monument protection and building height management. Consequently, broader historic urban landscape values, such as urban morphology, cultural continuity, and community memory, remain vulnerable.

Recent advances in digital heritage technologies, including GIS-based databases, digital archives, and heritage information systems, provide new opportunities for documenting and managing historic urban environments. At the same time, the UNESCO Historic Urban Landscape (HUL) approach advocates integrating cultural, social, and spatial

dimensions into heritage conservation. Building on previous research, this study develops a Digital Heritage Information Model (DHIM) and a Priority Conservation Framework to support HUL-oriented and sustainable conservation in Shenyang's Square City.

2. Literature Review

2.1 Digital Heritage Conservation

Digital heritage has emerged as an important field within heritage studies over the last two decades. Initially, digital technologies were primarily employed for documentation purposes, including digital photography, laser scanning, photogrammetry, and digital archiving. These techniques enabled the recording of heritage resources with unprecedented accuracy and efficiency.

As digital technologies evolved, heritage conservation increasingly incorporated Geographic Information Systems (GIS), Historic Building Information Modeling (HBIM), remote sensing, and digital twins. Scholars have demonstrated that these technologies not only improve documentation but also support heritage monitoring, risk assessment, and management. Digital heritage is therefore increasingly understood as an integrated information system rather than merely a documentation tool.

Despite these advances, many digital heritage projects remain focused on individual monuments or archaeological sites. Applications at the scale of historic urban landscapes remain relatively limited, particularly in rapidly urbanizing contexts where heritage management must address complex interactions among buildings, streets, landscapes, and communities. Consequently, there is a growing need for digital frameworks capable of supporting conservation at the urban scale.

2.2 Historic Urban Landscape (HUL)

Introduced by UNESCO in 2011, the HUL approach expanded conservation beyond individual monuments to include the broader urban context. It emphasizes the relationships among physical structures, spatial organization, social practices, economic activities, and environmental conditions. Although HUL has been widely applied in historic-city research, implementation remains challenging because of the complexity of collecting and managing large amounts of heritage information. Digital heritage technologies offer important opportunities for translating HUL principles into practical conservation tools.

2.3 Sustainable Heritage Conservation

Sustainability has become a key objective of contemporary heritage conservation. Sustainable conservation seeks to preserve cultural authenticity and collective memory while promoting social participation, economic vitality, and environmental responsibility. Recent studies suggest that digital technologies can enhance sustainability through improved information management, transparency, and long-term monitoring. Nevertheless, research integrating digital heritage, HUL principles, and sustainable conservation remains limited. This study addresses this gap through the case of Shenyang's Square City.

3. Study Area and Methodology

3.1 Study Area

The Square City is located in the historic center of Shenyang and constitutes the urban area surrounding the Shenyang Imperial Palace. As the birthplace of the Qing Dynasty capital, the area preserves important evidence of historical urban development, including traditional street networks, commercial districts, cultural landmarks, and residential neighborhoods.

The study area is also designated as the buffer zone of the Shenyang Imperial Palace World Heritage Site. Since the

World Heritage inscription in 2004, planning regulations have focused primarily on building height control and visual protection. However, previous research demonstrated that significant transformations of the historic urban environment have continued despite these conservation measures. Traditional hutongs, historic blocks, and community spaces have gradually disappeared as a result of redevelopment and commercial expansion.

The Square City therefore provides an ideal case for exploring how digital heritage technologies can support the conservation of historic urban landscapes within rapidly changing urban environments.

3.2 Research Framework

To address the challenges of heritage conservation in the Square City, this study develops a framework integrating digital heritage technologies with the Historic Urban Landscape (HUL) approach.

The framework consists of four stages: 1. Heritage resource identification; 2. Digital heritage database construction; 3. Priority conservation assessment; 4. Sustainable conservation strategy development.(Figure 1)

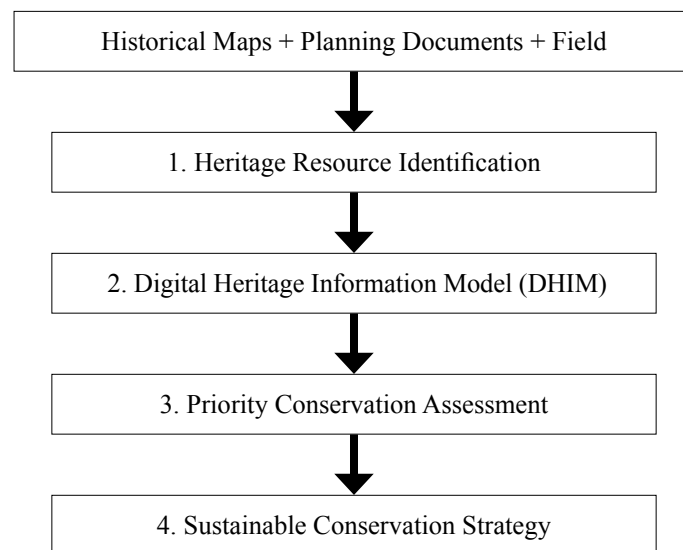


Figure 1. Research Framework of the Study

3.3 Heritage Resource Identification

Following UNESCO's Historic Urban Landscape framework, heritage resources within the Square City were classified into four categories:

1. Architectural Heritage: This category includes officially protected cultural relics, historic buildings, traditional residences, and significant commercial structures.
2. Urban Morphology: This category includes traditional street networks, historic blocks, spatial structures, and urban patterns that reflect the historical development of the city.
3. Historic Landscape Elements: Historic squares, landscape corridors, public spaces, and visual relationships associated with the World Heritage property were included in this category.
4. Intangible Heritage: Traditional commercial activities, community memory, local narratives, and cultural practices were identified as intangible heritage resources contributing to the historic character of the Square City.

3.4 Digital Heritage Database Construction

Based on the identified heritage resources, a Digital Heritage Information Model (DHIM) was established. The DHIM organizes urban data into four interconnected layers, allowing for a multidimensional analysis of the Square City's

evolution. The database integrates spatial, historical, cultural, and management information into a unified platform. The database allows heritage information to be updated continuously and provides a foundation for heritage monitoring and management (Table 1).

Table 1. Structure of the Digital Heritage Database

Layer	Components	Data Types
Spatial Layer	Physical structures and urban morphology	Buildings, streets (Hutongs), blocks, and 3D landscape elements.
Historical Layer	Chronological and archival evolution	Historical maps (1980–2024), chronological planning documents, and alignment records.
Cultural Layer	Values, expert critiques, and memory	Heritage significance, expert interview data, and administrative narratives.
Risk Layer	Threats and socio-economic pressures	Development pressure (financing paths), policy gaps, and physical condition.

3.5 Priority Conservation Framework

From Synthesizing Qualitative Data and Expert Insights and perspectives, a key innovation of the proposed framework is the transformation of qualitative expert knowledge into structured DHIM layers. The Cultural Layer incorporates expert observations on heritage authenticity. For example, concerns regarding the “Ming-style” reconstruction of Tongtian Street are evaluated against historical records, allowing the Historical Layer to verify spatial and temporal consistency and reduce the risk of inappropriate historical reconstruction. The Risk Layer integrates redevelopment-related information, including land-use policies, investment mechanisms, and development pressures. By linking these factors to heritage assets, the model identifies areas facing higher conservation risks. The framework also incorporates the spatial characteristics of the five administrative groups—Shuaifu, Zhengyi, Cuisheng, Pingshun, and Xihua—to assess the impacts of residential redevelopment on the historic urban landscape. The DHIM combines multiple data sources, including historical maps, field surveys, archival records, and documentation from the World Heritage nomination process (2003–2004). Information on designated cultural properties within the Square City is further integrated to support comprehensive heritage assessment and conservation planning (Table 2).

Table 2. Priority Conservation Framework

Priority Level	Criteria (Value + Risk)	Conservation Strategy	Specific Case Application (Shenyang Square City Examples)
Priority I (Immediate Conservation)	High Value + High Risk	Immediate Digital Documentation; Legal moratorium on demolition; HUL-based imaginative reuse.	Surviving Hutongs Networks: Specifically historic plots facing imminent redevelopment pressure, such as the North Zhong Street area (e.g., Huang House, Liu the Cobbler's House).
Priority II (Preventive Protection)	High Value + Low Risk	Preventive Monitoring (using HBIM); Routine maintenance; Strategic oversight of the buffer zone.	Designated Cultural Properties: The 15 officially listed heritage sites, including the Shenyang Imperial Palace, Chang Tso-lin's Residence, and the Bianye Bank.
Priority III (Selective Documentation)	Low Value + High Risk	Selective digital recording; Visual Impact Simulation; Negotiated design controls for new interventions.	1980s Residential Areas: Dilapidated modern apartment complexes (RACs) at risk of being replaced by massive commercial centers like Royal Plaza or Yuyuan Tourist Mart.
Priority IV (Routine Management)	Low Value + Low Risk	Routine urban planning management; Landscape integration; Enhancement of public green spaces.	Stable Modern Blocks: Established contemporary residential communities that comply with current height limits and do not threaten the historic urban grain (e.g., Pingshun RAC).

4. Results

4.1 Transformation of Historic Urban Fabric

During the past four decades, the Square City has experienced continuous redevelopment. Historical analysis revealed that the most significant transformation occurred after the introduction of market-oriented urban development policies in the 1990s. Large-scale residential redevelopment projects and commercial complexes gradually replaced traditional hutongs and historic urban blocks.

The previous study identified substantial losses of hutongs associated with both residential apartment developments and commercial redevelopment projects. Particularly after the World Heritage inscription in 2004, commercial investment accelerated within the Square City. Between 2009 and 2013, five large shopping centers were constructed, resulting in the demolition of traditional urban fabric despite compliance with building height regulations. The findings suggest that existing buffer-zone policies were effective in controlling visual impacts but insufficient for preserving historic urban morphology (Table 3).

Table 3. Major Transformations of the Square City (1980–2024)

Indicator	1980	1989	2004	2012
Disappeared Hutongs in Residential Apartment Communities (R.A.C.)	0	14	13	0
Disappeared Hutongs in Commercial Facilities (C.F.)	0	9	16	8
Other Redevelopment Projects	0	2	2	0

4.2 Digital Heritage Database Outcomes

The DHIM database successfully integrated multiple forms of heritage information into a single platform. Compared with conventional heritage inventories, the database offers several advantages: 1. Comprehensive documentation of heritage resources; 2. Spatial visualization of heritage distribution; 3. Integration of historical and contemporary information; 4. Support for monitoring and management. The database also enables heritage managers to identify relationships between individual monuments and the wider historic urban landscape.

4.3 Priority Conservation Assessment

The assessment results reveal several important patterns. First, surviving hutongs and historic street interfaces possess high heritage value because they preserve historical spatial structures and community memory. Second, many of these resources are exposed to substantial redevelopment pressure and therefore fall within Priority I conservation areas. Third, officially protected monuments generally exhibit lower risk levels because they benefit from legal protection and maintenance programs. The findings suggest that future conservation efforts should focus not only on individual monuments but also on the broader urban landscape and cultural context.

The DHIM enabled the identification of high-risk heritage areas and supported the prioritization of conservation resources based on the combined assessment of heritage value and redevelopment pressure.

5. Discussion

5.1 From Buffer Zone Protection to Digital Heritage Management

The Square City case shows the limitation of buffer-zone regulation. Although height control preserves the visual integrity of the Imperial Palace, hutongs and urban morphology continue to deteriorate. This reflects the weakness of monument-centered conservation.

The HUL approach expands heritage from monuments to urban systems, including spatial structure, cultural practices, and collective memory. However, operationalizing HUL remains difficult. Unlike conventional planning controls that primarily regulate physical development, digital heritage technologies enable the continuous integration of spatial, historical, and cultural information, thereby supporting more comprehensive conservation decision-making.

5.2 Digital Heritage as a Management Instrument

The DHIM transforms digital heritage from static documentation into a management tool. Compared with traditional inventories, it enables multi-layer integration and continuous updating of heritage information.

This shift reframes digital heritage as an operational infrastructure supporting evidence-based conservation and linking heritage attributes with urban development pressure.

5.3 Operationalizing the HUL Approach

A key challenge in HUL implementation is fragmented heritage information. The proposed database integrates buildings, streets, landscapes, and intangible heritage into a unified system.

This enables a relational understanding of heritage resources and helps identify systemic vulnerabilities in the historic urban fabric.

5.4 Implications for Sustainable Conservation

The framework contributes to sustainability in three ways. It supports cultural sustainability by preserving identity and memory, social sustainability by improving access to heritage data, and economic sustainability by informing heritage-led regeneration.

These dimensions are interdependent, requiring integrated conservation strategies rather than isolated approaches.

6. Conclusions

This study developed a Digital Heritage Information Model (DHIM) and a Priority Conservation Framework for the conservation of Shenyang's Square City, a historic urban area surrounding the Imperial Palace World Heritage Site. The research was grounded in previous findings on the morphological transformation of the Square City and addressed the need for more integrated heritage management tools.

The main contribution of this study lies in the development of a structured approach for organizing and linking heterogeneous heritage data, including spatial, historical, cultural, and risk-related information. This enables a more systematic understanding of heritage distribution and conservation priorities within complex urban environments.

The proposed framework demonstrates the potential of digital heritage technologies to support the implementation of the Historic Urban Landscape approach by improving information integration and enhancing decision-support capabilities. It provides a transferable model for managing historic urban areas facing similar redevelopment pressures in China and other rapidly urbanizing contexts.

This study is limited by the availability of historical data and the conceptual nature of the proposed database framework. Future research may incorporate GIS-based spatial analysis, digital twins, and real-time monitoring systems to further enhance heritage management.

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Author Biography:

Li Qin; female; born July 1972; Han ethnicity; native of Liaoning Province; major in Urban Planning.

Qian Liu; female; born April 1996; Han ethnicity; native of Anhui Province; major in Landscape Regeneration and Sustainable Design.

Zhiyao Zhuang; female; born April 1994; Han ethnicity; native of Luoyang City; major in Art Design.