

EXPANDING LAYERS OF KNOWLEDGE



RESEARCH, INNOVATION AND PERSPECTIVES ON TANGIBLE CULTURAL HERITAGE

Edited by

Carlo Bianchini, Marika Griffo, Francesca Porfiri



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Direzione scientifica:
Carlo Bianchini, Paolo Carata

Organizzazione scientifica:
Niccolò Cecconi, Francesco De Stefano, Marika Griffò, Francesca Porfiri

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Study Days

Venosa, 1-2 December 2025

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INTRODUCTION

Carlo Bianchini, Marika Griffo, Francesca Porfiri

This volume, *Expanding Layers of Knowledge. Research, Innovation and Perspectives on Tangible Cultural Heritage*, originates from the Study Days *Layers of Knowledge. Space, Time, and Meaning*, held in Venosa (Potenza) on 1-2 December 2025 as the concluding event of the activities carried out within Spoke 8 – *Sustainability and Resilience of Tangible Cultural Heritage* of the PNRR Extended Partnership PE5 CHANGES (*Cultural Heritage Active Innovation for Sustainable Society*). The relationship between the title of the conference and that of the present volume is intentional. The Study Days provided an opportunity to explore the multiple layers through which cultural heritage can be interpreted across space, time, and meaning. This publication expands that reflection by bringing together research outcomes, methodological approaches, and future perspectives that emerged through three years of collaborative work. More than a record of the event, the volume offers a broader overview of the processes through which knowledge on tangible cultural heritage is generated, integrated, interpreted, and shared. Within the framework of CHANGES, Spoke 8 addressed the challenges of Tangible Cultural Heritage through an integrated research model combining technological innovation, scientific methodologies, and humanistic approaches. Its activities focused on the development of digital infrastructures and knowledge systems, the implementation of evidence-based evaluation methodologies, and the definition of strategies aimed at promoting sustainable, resilient, and participatory models of heritage management.

The Study Days represented the culmination of this collective effort. Organised through the synergistic collaboration of the research groups involved in the Spoke 8, the event brought together, for the first time in a shared setting, all project partners alongside the teams whose initiatives had been funded through the cascade calls. This encounter generated a valuable opportunity for discussion and comparison among researchers, professionals, and institutions working from different disciplinary perspectives but within a common framework of objectives and methodologies. The resulting dialogue highlighted both the diversity of the research activities conducted during the programme and the coherence of the broader scientific vision that connected them. The thematic sessions reflected some of the principal methodological pillars developed within the project, including georeferencing strategies and digital inventories, the analysis of temporal stratifications in cultural heritage, and the semantic integration of heterogeneous datasets through advanced systems for querying, interpretation, and dissemination. Together, the contributions presented by partners and cascade-call projects demonstrated how archaeological research, architectural analysis, historical investigation, digital technologies, governance models, and community-oriented approaches can converge within an integrated framework for heritage knowledge.

The first section presents the projects developed by the partners of Spoke 8 and is organised into three thematic areas: *Archaeology and Historical Landscapes*; *Cultural Heritage, Communities and Value Creation*; and *Digital Methods and Information Systems for Heritage Knowledge*. The second section is dedicated to the

projects funded through the cascade calls and focuses on *Innovation, Governance and Intelligent Systems for Cultural Heritage*, highlighting the contribution of new research initiatives that have expanded the scientific scope and impact of the Spoke. Taken together, the essays collected in this volume document the results of a significant research experience while also offering a reflection on the future of heritage studies. They demonstrate how the conservation, interpretation, management, and enhancement of tangible cultural heritage increasingly require collaborative, interdisciplinary, and technologically informed approaches. Ultimately, the experience documented in these pages can be understood as an effort to build a lasting memory capable of crystallising multiple perspectives on cultural heritage and of preserving the richness of the dialogues, methodologies, and research practices that emerged throughout the project. The plurality of contributions collected in this volume reflects the diversity of approaches through which heritage can be investigated, interpreted, documented, and communicated, while also highlighting the increasingly central and transversal role of digital methodologies.

The dialogue fostered during the Study Days in Venosa showed that one of the most important legacies of Spoke 8 lies not only in the tools, datasets, and methodologies developed, but also in the network of relationships, exchanges, and collaborations that will continue to generate new research trajectories beyond the conclusion of the project.

The choice of Venosa as the venue for the Study Days carries a significance that extends beyond its role as one of the project's case studies. The Spoke challenge was to gather scholars, researchers, and professionals from institutions across Italy in a place that remains outside the country's most frequented academic and tourist destinations reflected one of the fundamental principles underlying both CHANGES and Spoke 8: the recognition that cultural heritage knowledge and innovation should contribute to strengthening the visibility, accessibility, and resilience of territories beyond established centres of attraction. For two days, Venosa became a national hub for discussion on cultural heritage research, bringing together scholars and research teams from across Italy in a collective reflection on the challenges and opportunities facing contemporary heritage studies, demonstrating how places often perceived as peripheral can instead occupy a central position in the production of scientific knowledge and cultural value. In this sense, the location itself became part of the message conveyed by the project, reaffirming the importance of investing in cultural landscapes whose richness deserves broader recognition.

Given the venue, a particular attention was devoted to two case studies of the Spoke: The Complex of the *Santissima Trinità* in Venosa and the Cathedral of Acerenza. An exhibition was organised during the Study Days to present the 3D documentation campaign results; while the guided visits to both sites, held by the allowed participants to engage directly with the local architectural and archaeological heritage. These activities fostered a productive dialogue between technological innovation and historical interpretation, showing how digital tools can support broader processes of cultural understanding and heritage enhancement.

BIM/GIS INTEGRATION FOR THE MANAGEMENT OF TANGIBLE CULTURAL HERITAGE: METHODOLOGY AND DEVELOPMENT OF AN OPEN-SOURCE WEB PLATFORM

**Mattia Mangia¹, Carla Di Biccari², Roberto Vergallo³, Antonio Altavilla⁴,
Giovanni Coppola⁴, Marika Griffo⁵, Simone Lucchetti⁵**

*1: University of Salento, Department of Innovation Engineering, Lecce
mattia.mangia@unisalento.it*

2: University of Salento, Department of Cultural Heritage, Lecce

3: Pegaso University, Department of Information Science and Technology, Naples

*4: Vidyasoft s.r.l., Lecce,
antonio.altavilla@vidyasoft.it*

*5: Department of History, Design and Restoration of Architecture, Sapienza University of Rome
marika.griffo@uniroma1.it, simone.lucchetti@uniroma1.it*

Keyword Cultural Heritage; BIM/GIS Integration; H-BIM; Digital Information Management; Scan-to-BIM

Abstract *The VILLAE project – Virtual Integration for Landscape and Legacy Architecture Enhancement, developed within the PNRR PE5-CHANGES (Spoke 8) program, addresses the challenge of digital management of tangible cultural heritage through the development of an innovative web platform based on the integration of BIM (Building Information Modeling) and GIS (Geographic Information Systems) technologies). The main objective is to overcome the fragmentation between traditionally separate information systems, creating a unified environment accessible even to small local public bodies with limited resources. Inspired by the ISO 19650 and UNI 11337 standards, the VILLAE project has set itself the goal of developing a completely open-source software architecture. The platform is based on the use of innovative libraries for IFC file parsing, geospatial 3D visualization and integrated data management. In this way, it was possible to implement a platform based on BIM/GIS integration for the management of information on the Historical and Cultural Heritage.*

INTRODUCTION

The digitization of cultural heritage is now a strategic priority to ensure the conservation, efficient management and enhancement of historical assets. However, one of the most significant problems that hinders integrated management is the technological fragmentation between the systems responsible for representing the territory (e.g. Geographic Information Systems, GIS) and those focused on the individual building (in particular Building Information Modeling, BIM).

The integration of BIM and GIS has been extensively studied in the last decade as a means of connecting object-based building data with spatial and environmental information (Amirebrahimi et al., 2016; Azari et al., 2025; Zhu & Wu, 2022). Applications cover multiple areas, including new

construction (AMIREBRAHIMI et al., 2016) infrastructure management (HUANG et al., 2021; VILGERTSHOFER et al., 2017; XIA et al., 2022) urban digitization and, increasingly, documentation and conservation of cultural heritage (COLUCCI et al., 2023; DIONIZIO et al., 2025; MASCORT-ALBEA et al., 2020). In the field of heritage, BIM–GIS integration has been mainly explored to support the risk assessment, documentation and management of historical assets exposed to natural hazards (AVENA et al., 2021) (LU et al., 2020) (KANAK et al., 2020) (AMIREBRAHIMI et al., 2016; BANFI et al., 2020; SU, 2025). In terms of HBIM (Heritage BIM, for cultural-historical heritage), it is also important to analyze the information management aspect, in order to determine the balance point where the required level of detail and the actual usefulness meet (LOVELL et al., 2023; SIEWCZYŃSKI & SZOT, 2025). On this point of balance and on the overall sustainability of the HBIM methodology and BIM/GIS integration, it is also important to address the issue of open-source and existing commercial solutions (CHEN et al., 2018), (CONGIU et al., 2023) and the acquisition of the necessary skills, on which pre-entry education also plays an important role (ACKE et al. 2024). In fact, BIM presents technological and economic barriers for its adoption in small local authorities, custodians of a large part of Italy's widespread heritage. The VILLAE project, funded under the PE5-CHANGES Extended Partnership (Spoke 8), fits into this scenario. The primary objective of the research was the development of a unified BIM/GIS platform, based entirely on open-source technologies, capable of offering accessible, scalable Digital Information Management tools compliant with national and European standards.

1. OVERALL PROJECT METHODOLOGY

The project was developed based on an agile methodological approach, characterized by the progressive involvement of stakeholders and project partners from the initial stages and oriented towards the continuous verification of the results through application case studies. The research activities have integrated state-of-the-art analysis, multi-scale digitization processes and the development of a web-based platform for the management and integrated use of BIM and GIS data, supported by validation and scientific dissemination actions. The entire process was guided by the main reference standards for information management, in particular by the ISO 19650 standard for the general principles of Building Information Management and by the UNI 11337 series for the Italian national context. Interoperability between systems and data has been ensured through the adoption of open and standardized formats, including IFC for BIM models, GeoJSON for geographic vector data, and 3D Tiles for web visualization of geospatial three-dimensional models. Moreover, in order to promote and enhance the results obtained, training and dissemination activities were conducted regarding BIM, GIS and workshops on the solution developed, to collect feedback from experts in the sector on the potential use of this type of applications. The digitization of assets has followed a consolidated workflow that starts with the integrated data acquisition of photogrammetry from drones (UAVs) and terrestrial laser scanners (TLS). Metric consistency between the two datasets was ensured by a topographic support network and Ground Control Points (GCPs). The processed and recorded point clouds formed the geometric basis for H-BIM (Heritage BIM) modelling.

2. THE BIM/GIS WEBAPP OF THE VILLAE PROJECT

The platform developed allows you to create and visualize integrated BIM/GIS 3D digital environments, georeferenced and inserted in the real territorial context. It maintains the semantic structure of BIM models even after conversion for web publishing: each element remains selectable and can be queried, with properties accessible in JSON format through a simple interface that allows the choice of individual objects or entire IFC categories. The environment allows the simultaneous interrogation of multiple BIM models and the joint visualization of 3D models and GIS layers (2D with Leaflet and 3D with CesiumJS), with Three.js-based rendering in React. The architecture is modular, based on containerized microservices: the frontend is a Single Page Application and the backend manages APIs and processes, while dedicated services take care of IFC parsing, model conversion and streaming optimization. Models are transformed into formats that allow progressive loading, including 3D Tiles, while maintaining informative metadata. The entire system uses open-source technologies and a spatial data infrastructure that ensures integrated BIM/GIS management, making the platform accessible via browser even on devices with limited resources. The 3D BIM/GIS Webapp preserves the geolocation and semantics of BIM models, in fact even downstream of the conversion process the elements can be selected and queried. You can select individual IFC elements or categories (e.g. IfcColumn for columns). In addition, compared to what BIM viewers do on the market, a series of features have been implemented that in fact constitute an "HBIM Use Case" for the use of the "temporal" dimension of the archaeological site. The WebApp allows you to define, through a Time Slider, a time interval of the user's choice that intercepts the temporal attributes of each element, i.e. its estimated date of creation and removal. For example, if you set the Time Slider to Year Start 1100 BC and Year End 2100 AD, all BIM models in the scene will be shown or hidden depending on whether their Time Phase attribute is within this range Figure 1.



Fig. 1. Example screenshot of the HBIM model of the temple of San Lorenzo in Miranda, Rome.

3. CASE STUDIES AND VALIDATION

The methodology was validated on two pilot case studies located in the province of Lecce (Puglia Region, n.d.), selected for their typological diversity and complexity (fig. 5). The Palazzo Ducale Filomarini in Cutrofiano, with its historical stratification and articulated geometries, has made it possible to test the management of complex decorative elements and irregular spaces. The Archaeological Industrial Museum of Terra d'Otranto (MAITO) in Maglie, characterized by large volumes and metal structures, has verified the ability of the system to manage large spaces and components of industrial archaeology. The complete workflow was applied for both: from integrated surveying to H-BIM modeling, up to import into the platform with automatic georeferencing based on IFC coordinates. Interoperability tests confirmed the correct reading of geometries and semantic data.



Fig. 2. HBIM model of the Archaeological Industrial Museum of Maglie (MAITO).

The main result is the release of a working prototype of a BIM/GIS platform, validated by stakeholders and populated with digital datasets of case studies. The platform demonstrated high display and query performance even with complex models. In parallel, as part of other project activities, training materials were produced to facilitate the adoption of the tool and the understanding of BIM and GIS for local authorities and contracting authorities. The solution has proven to be scalable and replicable, offering a reference model for the management of widespread assets.

4. CONCLUSIONS

The VILLAE project demonstrates how BIM/GIS integration represents an essential strategic tool for the sustainable management of cultural heritage. Overcoming the historical dichotomy between territorial and architectural scale, the platform developed enables a holistic vision of the asset in its context. The choice of open source is not only technological but ethical, enabling a democratization

of digital tools that is essential for the Italian context. Compliance with ISO 19650 and UNI 11337 standards guarantees the quality and longevity of the data produced. The results of the VILLAE project, following a discussion with various stakeholders in the sector (Universities, Local Authorities, archaeology, architecture and engineering professionals), have generally aroused a strong interest for the characteristics demonstrated, such as the flexibility for the creation of ad-hoc BIM/GIS applications capable of implementing specific unconventional HBIM uses that are not available in commercial software. In the future research directions that the VILLAE project has outlined, it will certainly be a priority to deepen the integration of BIM and GIS with additional data sources such as sensors and the overall body of documentation that increasingly needs a clear digital transition of the Public Administration in the Cultural Heritage sector, in line with national and European directives.

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