

## Article

# H-GIS-BIM Integration as a Knowledge-Making Tool for Heritage in Italian Marginal Areas

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## Abstract

This research investigates the development of integrated knowledge systems for built heritage located in Italian Inner Areas, marginal territories characterised by socio-economic fragility and the progressive weakening of traditional settlement systems. Within these contexts, built heritage is deeply interconnected with the landscape as a result of long-standing interaction processes between man and territory. Yet it is often affected by limited, fragmented information and inadequate digital management frameworks. This study addresses these issues by developing a methodological approach grounded in multidisciplinary, multiscale, transscale, and diachronic principles to reconnect territorial and architectural dimensions within a unified interpretative framework. The Alpine municipality of Dosso del Liro (Northern Italy) was selected as a representative case study for testing the applicability of an integrated H-GIS-BIM workflow under conditions typical of marginal contexts. The research combines desk-based and field-based investigations. Information was organised with regard to the historical and diachronic features of assets and then integrated into a digital environment developed using GIS, HBIM, and conversion workflows. The results demonstrate the accessibility of H-GIS-BIM strategies through a methodological approach and their support for enriching analyses of diffuse heritage, while also highlighting current limitations regarding workflow, interoperability, semantic preservation, and dynamic data updating.

**Keywords:** BIM-GIS integration; H-GIS-BIM; inner peripheries; rural heritage; alpine heritage; Italian Inner Areas



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## 1. Introduction

### 1.1. Heritage in Italian Marginal Areas

Italian marginal territories are characterised by the increasing exposure of their heritage to processes of decline driven by long-term socio-economic transformations. In response to these conditions, the Italian Government launched the National Strategy for Inner Areas (SNAI) in 2013. The strategy identified and classified municipalities according to their accessibility to centres providing essential services, and promoted place-based development through targeted measures that address demographic, economic, infrastructural, and social fragilities [1].

Within these territories, both built assets and broader landscape structures have gradually lost function and meaning as a result of transformations that reshaped local economies,

productive practices, and settlement systems throughout the twentieth century [1]. These processes intensified after the Second World War, when industrialisation, urbanisation, and the contraction of agro-sylvo-pastoral activities accelerated depopulation and territorial abandonment, contributing to the critical conditions observed today (Figure 1) [2].



**Figure 1.** Rural settlement on the ridge of *Monte Tremezzo* in the SNAI area of *Lario Intelvese e Valli del Lario e del Ceresio* (Northern Italy) (photo: L.P.).

Their consequences extend beyond the abandonment and physical deterioration of built heritage. They also involve the weakening of the cultural and social frameworks that have historically sustained buildings, settlements, and productive landscapes. As traditional uses decline and local communities shrink, architectural artefacts and territorial structures progressively lose their functional roles and symbolic significance. The knowledge, practices, and cultural values embedded in them are consequently at risk, further reinforcing processes of marginalisation and invisibility.

Given the nature of several Inner Areas—historically linked to the primary sector—the built heritage of these territories is often rural and directly contributes to the landscape's historical and spatial configuration. Despite this relevance, such resources frequently remain outside structured regeneration and investment policies. Their exclusion reflects several interrelated factors, including the limited economic viability of conservation and compatible reuse interventions, negative perceptions of rural buildings, changing living standards, the decline of their original functions, and their distance from centres offering services, employment, and stronger economic opportunities.

These conditions are accompanied by a structural deficit in knowledge, affecting both the availability of data on heritage itself and the organisation of existing information. This deficit does not derive solely from limited documentation. It also reflects institutional and organisational fragmentation, uneven responsibilities, disciplinary separation, methodological shortcomings, and information-management systems that are poorly suited to the cumulative and interoperable study of diffuse heritage [3]. As discussed below, many of the systems currently employed for heritage documentation, management, and dissemination remain based on conventional, sometimes outdated, GIS structures. Although these systems continue to provide essential functionalities, they frequently exhibit limitations



in representation, granularity, multidisciplinary, multiscale, and the integration of territorial and architectural information.

The research, therefore, addresses heritage knowledge as a preliminary condition for recognising the cultural and territorial significance of these assets and for assessing their potential role within future strategies of conservation, management, and reactivation. This requires an approach that reflects the specific nature of rural built heritage, whose significance cannot be understood by considering individual buildings in isolation from the territorial, environmental, productive, and settlement systems to which they belong. The architectural scale of the individual artefact and the broader scales of the settlement and landscape must consequently be incorporated into a unified analytical workflow.

Accordingly, the study addresses both the fragmentation of existing information and the lack of coherent methodological frameworks capable of connecting the territorial and architectural domains. Rather than treating buildings and landscapes as separate objects of inquiry, it considers them interdependent components of a single system. Their interpretation, therefore, requires integrating spatial, historical, morphological, typological, functional, material, and environmental information across different scales and chronological phases.

Within this framework, Historic Landscape Characterisation (HLC) provides a significant methodological reference. Developed to interpret landscape as the cumulative outcome of long-term transformations, HLC shifts attention away from isolated and selectively recognised assets towards the historic character of the territory as a whole [4]. Its emphasis on time depth, relational interpretation, comprehensive coverage, and character-based spatial units is particularly relevant to an application to alpine rural heritage, whose significance often lies in transscale relationships. In this study, HLC principles inform both the interpretation of the landscape and the semantic organisation of data, supporting the construction of a diachronic information structure that can be extended from territorial units to architectural objects.

### *1.2. Integrated H-BIM-GIS Environments as a Resource for the Study of Inner Areas*

To address this situation, BIM-GIS integration can serve as a valuable tool for overcoming several methodological and technical challenges. Over recent decades, this topic has assumed a central role in the management of information concerning both the built environment and the territory.

From a conceptual perspective, BIM and GIS are founded on distinct paradigms. The first one is designed for the object-oriented and parametric modelling of buildings, with particular focus to the description of technical components and lifecycle management. The latter, by contrast, is conceived for the analysis of complex spatial phenomena, prioritising georeferenced data, topological relationships, and the multiscale organisation of territorial information. On the one hand, these differences generate several operational challenges, including geometric compatibility, coordinate reference systems, semantic correspondence between entities, and, more generally, interoperability between formats and software platforms. On the other hand, their integration has been widely recognised as a key opportunity for managing heritage within a multiscale and multidisciplinary framework [5–7].

The literature has addressed these challenges through different integration strategies [5,8]. Some approaches operate at the application level, enabling reciprocal import, visualisation, or synchronisation between BIM and GIS software environments. Others focus on the process level, developing coordinated workflows in which the two domains maintain their specific characteristics while communicating through intermediary formats or services. A third research direction addresses the data level, investigating semantic interoperability through standards such as IFC and CityGML and their transformation

using direct conversion procedures, Extract-Transform-Load (ETL) tools, or intermediate semantic models [5–7].

Within the field of cultural heritage, these approaches have been explored through several representative studies. Dore and Murphy (2012) [9] pioneered the integration of HBIM and GIS through IFC-to-CityGML conversion. Colucci et al. (2020) [10] compared direct BIM import into ESRI ArcGIS Pro (version 2.4.3) with IFC-to-CityGML workflows, highlighting the trade-off between operational simplicity and semantic interoperability. Barazzetti et al. (2017, 2021) [11,12] investigated application-level integration through Autodesk InfraWorks for territorial-scale heritage assessment, while other authors have extended BIM-GIS environments towards collaborative web platforms and decision-support applications for heritage management [13–15].

Although these studies have produced significant advances, they continue to highlight persistent challenges in semantic preservation, bidirectional updating, interoperability across standards, and the operational complexity of advanced workflows. These criticalities become even more significant in Inner Areas, where data availability, financial resources, and specialised technical expertise on such systems are often limited.

Hence, the research is situated in this context, investigating a workflow-oriented approach based on widely adopted software environments, prioritising operational accessibility, methodological transferability, and practical applicability while accepting a conscious compromise regarding complete interoperability.

### 1.3. Research Objectives and Contribution

Against this background, this work explores the potential of an integrated H-GIS-BIM environment—including the H (Heritage) for both GIS and BIM, highlighting the declination of the process—to support relational, multiscalar, transcalar, and diachronic knowledge production in complex heritage contexts.

The purpose is not simply to place digital building models within a geographic setting, but to establish an information framework through which architectural artefacts, settlement dynamics, land-use transformations, and historical processes can be examined in relation to one another. The study, therefore, investigates how integrated digital environments can contribute to more coherent and operationally applicable knowledge frameworks for the documentation, interpretation, conservation, management, and potential reuse of built heritage in marginal territories. In this scope, *documentation* refers to the acquisition and organisation of the quantitative and qualitative characteristics of the objects under investigation. *Management* is understood in a dual sense, encompassing both the physical governance of heritage and the organisation, maintenance, and updating of the related information. *Decision support*, finally, concerns the use of knowledge produced through these processes to define criteria and guidance for safeguarding heritage's character while allowing informed, compatible transformations.

Therefore, the contribution of the research lies in the combination of three interrelated elements. First, it transfers principles derived from HLC into a semantic structure capable of organising diachronic information across both territorial and architectural scales. Second, it tests a pragmatic H-GIS-BIM workflow by which HBIM entities can be transformed into georeferenced and queryable components of a GIS-based information system. Third, it assesses the applicability of this combined approach in an Italian Inner Area, where information is scarce and fragmented, heritage is diffuse, and resources are comparatively limited. The novelty does not reside in any of these elements considered in isolation, but in their methodological and operational integration within a single knowledge-making workflow.

## 2. Materials and Methods

### 2.1. Inner Areas, Scattered Heritage and Methodological Premises

In the Italian context, the so-called Inner Areas refer to territories located at a significant distance from the main centres that provide essential services, particularly healthcare, education, and mobility, and are frequently affected by demographic, economic, and infrastructural fragility. These are predominantly mountainous and rural regions, marked by processes of marginalisation rooted in long-standing structural weaknesses and further intensified by the socio-economic transformations that followed the Second World War. During this period, industrialisation and urbanisation progressively concentrated population, resources, and functions within major urban centres, generating widespread depopulation, the contraction of local productive activities, and the weakening of historic settlement systems [1].

Within these contexts, heritage emerges as an extensive and articulated system closely related to the historical dependence of these territories on the primary sector. Its character is predominantly rural and includes settlements, buildings, and features such as paths, dry-stone walls, terraces, water-management structures, agrarian layouts, and other artefacts generated through the historical interaction among local communities, productive activities, and environmental conditions. These components are closely connected to the landscape and its resources and should be interpreted as parts of a single relational system. Many of the objects under consideration originated in response to specific needs associated with the use, control, and management of the territory. Understanding the relationships between their form, function, and context consequently requires reconstructing the historical processes, practices, and cultural meanings through which they developed.

The issues nowadays affecting this heritage arise precisely from the disruption of this relational system. The decline of traditional activities has progressively deprived buildings, infrastructures, and productive spaces of their original functions, leading to abandonment, inappropriate transformation, or complete disappearance. This functional decline is accompanied by a loss of meaning, linked to the weakening of the practices, knowledge, and cultural values that once sustained these assets [16]. Heritage consequently becomes less legible, both in its material components and in the relationships that connect it to the wider territory.

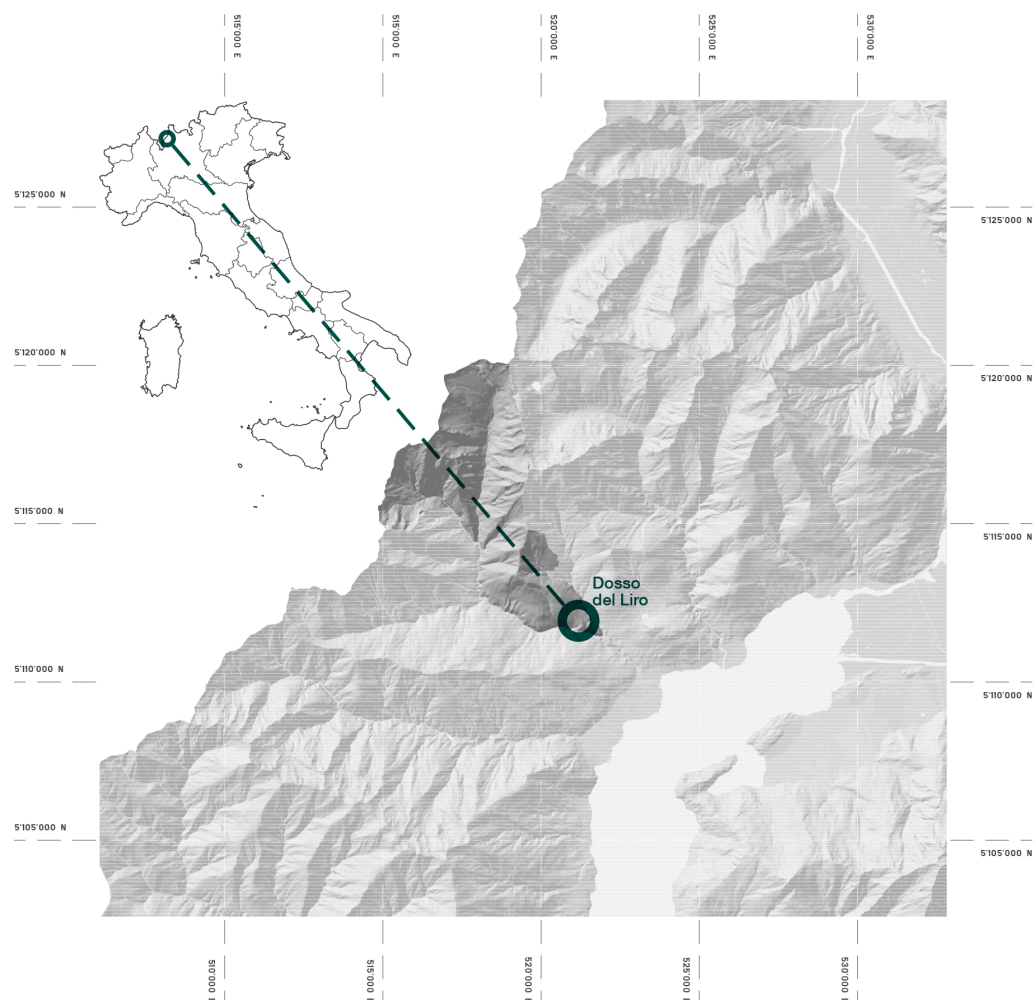
These conditions require drawing on multiple disciplinary perspectives. Particularly relevant within the Italian academic context are studies on rural architecture [17–19], historical geography [20–22], and landscape archaeology [23,24]. These fields support an interpretation of the territory as the outcome of long-term processes, legible through the relationships among environmental, settlement, and productive components. Architectural disciplines provide the methods required to investigate the material, constructive, spatial, and typological characteristics of the built heritage directly [25–28]. At the same time, territorial sciences enable these elements to be contextualised within broader spatial and functional systems.

These premises call for a methodological approach grounded in four key principles. The first is *multidisciplinarity*, understood as the active integration of different disciplinary contributions within a unified interpretative framework, rather than their mere juxtaposition. The second is *multiscalarity*, which is required to address the territorial, settlement, and architectural dimensions of heritage. A *transcalar* perspective extends this principle by examining the relationships between scales, highlighting how territorial processes influence individual architectural artefacts and how these, in turn, contribute to the broader configuration of the landscape [29]. Finally, a *diachronic* approach is essential for understanding the genesis and evolution of present-day configurations. It restores temporal

depth to the analysis and enables heritage to be interpreted as the outcome of successive transformations, continuities, and adaptations.

## 2.2. Case Study: Dosso del Liro

The methodological experimentation was conducted in the municipality of *Dosso del Liro*, in the Province of Como, within the mountainous region of the Lepontine Alps (Figure 2).



**Figure 2.** Geographic framework of Dosso del Liro (Map: L.P.).

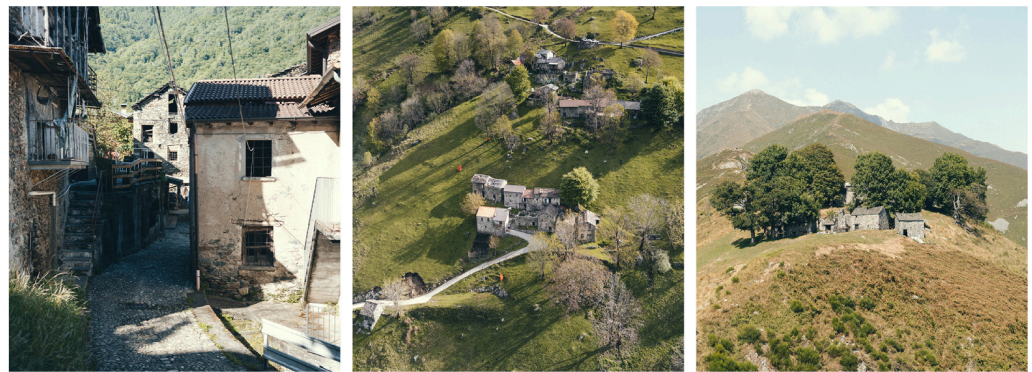
The case study was selected because it combines pronounced geographical and socio-economic marginality with the persistence of a historically structured rural landscape. These conditions are formally recognised through their inclusion in the SNAI strategic area of *Alto Lago di Como e Valli del Lario* [30].

The municipality, similarly to others in this region, is characterised by a low-density settlement system comprising historic urban agglomerations, isolated buildings, and structures associated with agrosylvopastoral practices. Its current layout results from a centuries-long process of adaptation to environmental conditions and local productive needs, which generated a diffuse built heritage closely integrated with the landscape (Figures 3 and 4).





**Figure 3.** Panoramic view of the Liro Valley. The case study covers the whole mountain in the foreground (Photo: L.P.).



**Figure 4.** Comparison between the settlements of Dosso del Liro (permanent, 600 m asl ca.), *Caiasco di Sotto* (monte, 1000 m asl ca.), and *Piaghedo* (alpe, 1300 m asl ca.) (Photo: L.P.).

More specifically, the historical, vertical organisation of the mountain landscape remains legible in the distribution of settlements and productive areas across successive altitudinal zones. These include permanent settlements at lower elevations, intermediate seasonal settlements locally known as *monti*, alpine pasture settlements or *alpi*, and the more remote high-altitude grazing areas known as *avert* [31] (Figure 4). Together, these components supported the seasonal use of mountain resources by connecting residential, agricultural, forestry, and pastoral activities across different elevations. The surviving heritage associated with this system includes, among other elements, houses, stables, barns, fountains, retaining and dry-stone walls, terraces, roads, mule tracks, and paths. It also encompasses historically defined land uses and productive landscapes, including pastures, meadows, crop gardens, and chestnut groves. These examples are obviously not exhaustive, but are enough to illustrate the close relationship among built structures, infrastructure, land management, and the seasonal organisation of productive practices.

Since the post-war period, the area has experienced depopulation and major changes in its local economy, accompanied by the progressive contraction of traditional activities [1,32]. Unlike the more accessible settlements downstream along the shores of Lake Como, Dosso del Liro did not undergo an equivalent transition towards new economic sectors, particularly tourism. The decline of the former productive system was therefore not offset by comparable sources of employment and income, contributing to a gradual loss of economic vitality. This process weakened the historic settlement system, affecting both the continuity of building use and the maintenance of territorial structures. As a result, much of the built

heritage, although still formally recognisable, has become increasingly detached from the practices and functional relationships that originally shaped it [16].

Therefore, Dosso del Liro is particularly relevant for investigating diffuse heritage that largely falls outside established protection frameworks yet remains fundamental to the territory's historical character and identity. Its analysis brings together several issues central to the research: the fragmentation of available information, the difficulty of interpreting relationships between territorial and architectural scales, and the need for knowledge systems that support conservation, reactivation, and reuse.

From a methodological perspective, the case study also provides an appropriate context for testing the applicability of an integrated H-GIS-BIM approach under operational conditions that are far from ideal. These include limited and uneven data availability, heterogeneous documentary sources, and the need to construct substantial parts of the knowledge framework through new research. Since such conditions recur across many Inner Areas, the experimentation also provides a basis for assessing the method's transferability to comparable rural and mountainous contexts.

The selection of Dosso del Liro thus has both an applied and a demonstrative value. It enables the proposed method to be tested in a specific territorial setting and to assess whether an information system structured according to multidisciplinary, multiscalar, transcalar, and diachronic principles can reduce existing knowledge fragmentation and provide a more coherent basis for future conservation, planning, and reuse strategies.

### 2.3. Data Collection

A study of this kind must first identify the information required to understand the heritage system outlined above. Since rural heritage derives much of its significance from its relationships with the surrounding territory, data collection cannot be limited to individual buildings and artefacts. Still, it must encompass the broader environmental, settlement, and productive context in which they developed. The investigation, therefore, operates across multiple scales, from the territorial level—considered here at the supra-municipal scale—to individual buildings and their constituent elements, reflecting the principle of multiscalarity introduced in the methodological framework.

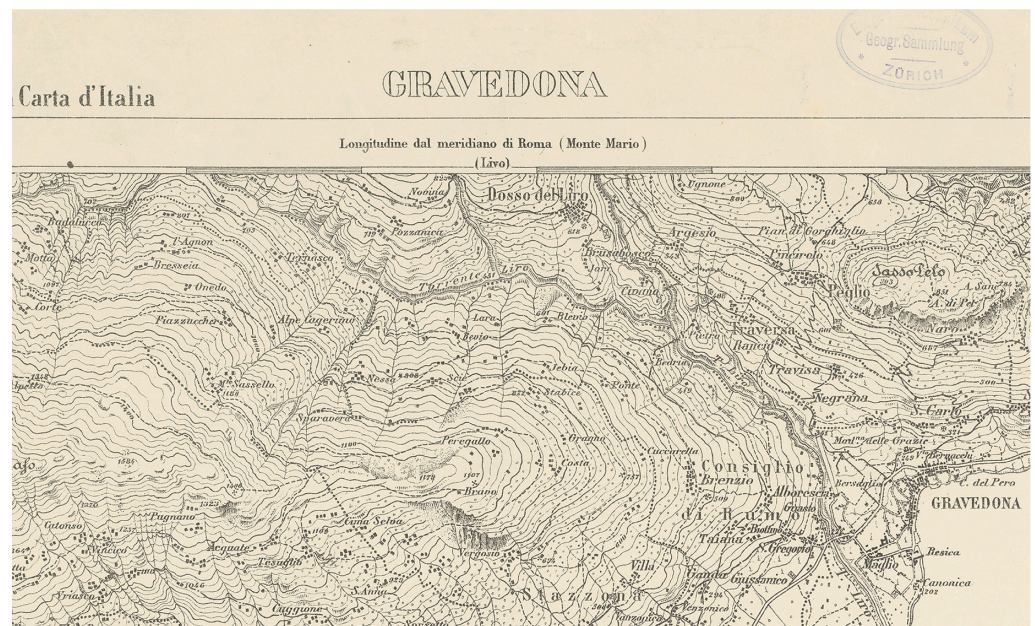
The non-monumental nature of this heritage makes systematic documentation particularly challenging. Many rural assets remain only partially recorded in existing information systems and are often poorly documented also by historical sources. Consequently, no single source provides a sufficiently comprehensive knowledge base. Existing documentation must therefore be complemented by the direct acquisition of new information to fill documentary gaps, verify previous interpretations, and produce data at the level of detail required for architectural investigation. Rather than following a linear sequence, these two forms of investigation continuously inform one another through an iterative process of acquisition, interpretation, validation, and refinement.

For these reasons, data collection was organised into two complementary operational domains: *desk-based* and *field-based* research.

The desk-based phase aimed to collect, assess, and systematise information already available from heterogeneous sources.

These included geospatial datasets, historical and contemporary cartography (Figure 5), cadastral records, planning documentation, historical and recent aerial imagery, archival sources, documentary evidence, and photographic collections. This phase established the initial knowledge framework required to understand the study area and to guide subsequent investigations.





**Figure 5.** One of the historical maps used to analyse the landscape’s historical features (Source: *Carta d’Italia 1:25,000. Gravedona*. Firenze: Istituto Geografico Militare, 1868–1925: 17 II NO/1906(1868-). Firenze: Istituto Geografico Militare, 1906. ETH-Bibliothek Zürich, K P 359002: 17 II NO Ed. 1906, <https://doi.org/10.3931/e-rara-147307>. Public Domain Mark).

However, the use of existing documentation also revealed several limitations. Information relevant to the study of built heritage proved highly fragmented across institutions, archives, and administrative repositories, often characterised by heterogeneous formats, inconsistent spatial and semantic resolution, incomplete coverage, and different update cycles. Historical sources varied considerably in accuracy, completeness, and interpretability. Consequently, significant efforts were required to harmonise, compare, and critically interpret these heterogeneous sources before they could be integrated into a coherent knowledge framework.

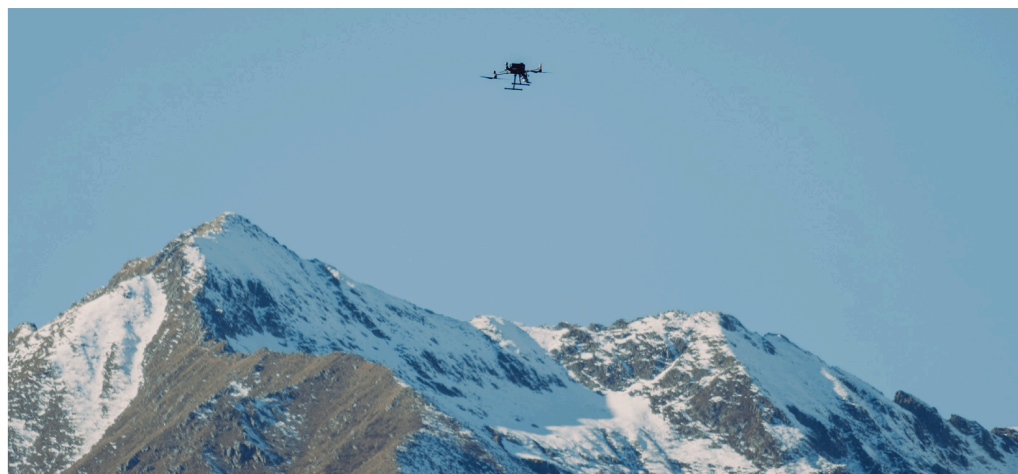
Alongside this activity, a field-based phase was undertaken to generate new information directly from the study area and to obtain the geometric and semantic detail required at the architectural scale. Here, the architectural scale refers to the level at which individual building components can be identified and documented, as these often preserve evidence of traditional construction practices and techniques that are progressively disappearing. Accordingly, the survey strategy was designed to achieve a target spatial resolution of approximately 1–2 cm for both photogrammetric and LiDAR acquisitions, enabling the reliable representation of such features.

To ensure the geometric reliability of the datasets and enable integration into a H-GIS-BIM environment, all acquisitions were referenced to a network of Ground Control Points (GCPs) surveyed using GNSS observations within the RDN2008/UTM Zone 32N reference system (EPSG:7791).

Field experimentation was deliberately concentrated on the historic permanent settlement of *Civano* (500 m asl ca.), selected as a representative sample to balance methodological completeness with the practical constraints of data acquisition, processing, and modelling.

The survey campaign combined complementary geomatics techniques collected across multiple field sessions. These included UAV photogrammetry, multispectral imagery, airborne LiDAR for territorial and morphological documentation, terrestrial photogrammetry, and mobile SLAM LiDAR surveying. Airborne acquisitions were performed using a Matrice 300 RTK (DJI, Shenzhen, China) equipped with a Zenmuse L1 sensor (DJI, Shenzhen,

China) (Figure 6), while rapid documentation of the built environment was undertaken using an Hovermap (Emesent, Milton, Australia) SLAM system.



**Figure 6.** Aerial survey with a DJI Matrice 300. This technique improves not only the quality of the information, but also the data coverage in scarcely accessible areas (Photo: L.P.).

Together, these techniques enabled the acquisition of ca. 16 ha of territorial landscape and 1.5 ha of built fabric within approximately one fieldwork day, demonstrating the operational efficiency of the proposed workflow for extensive rural contexts.

The resulting datasets consisted primarily of high-resolution point clouds and orthophotos generated using Agisoft Metashape Pro (version 2.0.2), DJI Terra (version 3.6), and Emesent Aura (version .10.2). These products provided the geometric basis for the subsequent semantic modelling process.

Ultimately, the outputs of the desk-based and field-based investigations constitute the informational foundation of the integrated workflow. Existing documentation and territorial datasets were used to construct the GIS knowledge base, whereas the survey-derived point clouds and orthophotos provided the geometric reference for HBIM development (Table 1). Their subsequent integration enables the construction of a coherent information environment in which territorial and architectural knowledge is progressively connected within a unified H-GIS-BIM framework.

**Table 1.** Summary of the main sources of desk- and field-based phases.

| Source                       | Reference Scale                   | Software                                | Output                                                    | Knowledge Contribution                                         |
|------------------------------|-----------------------------------|-----------------------------------------|-----------------------------------------------------------|----------------------------------------------------------------|
| Geospatial datasets          | Territorial, Urban                | ArcGIS Pro 3.7.1, QGIS 3.44.0-Solothurn | Georeferenced vector or raster layers                     | Territorial, environmental, urban, and infrastructural context |
| Urban planning documentation | Municipal                         | ArcGIS Pro 3.7.1, QGIS 3.44.0-Solothurn | Structured attribute tables and thematic layers           | Territorial, urban, and heritage context                       |
| Historical cadastres         | Territorial, Local, Architectural | ArcGIS Pro 3.7.1, QGIS 3.44.0-Solothurn | Georeferenced cadastral maps and digitised land registers | Settlement and land-use evolution                              |
| Historical cartography       | Territorial                       | ArcGIS Pro 3.7.1                        | Georeferenced historical maps                             | Territorial, urban, and landscape evolution                    |



Table 1. *Cont.*

| Source                                               | Reference Scale            | Software                                                                      | Output                                  | Knowledge Contribution                                           |
|------------------------------------------------------|----------------------------|-------------------------------------------------------------------------------|-----------------------------------------|------------------------------------------------------------------|
| Documentary, bibliographic, and iconographic sources | Territorial, Architectural | ArcGIS Pro 3.7.1                                                              | Digitised evidence and attribute tables | Historical context                                               |
| Exploratory field survey                             | Territorial, Urban         | ArcGIS Pro 3.7.1, QGIS 3.44.0-Solothurn                                       | Notes, observations, validation records | Settlement and landscape interpretation                          |
| Photographic survey                                  | Territorial, Architectural | Adobe Lightroom Classic 15.4.1, ArcGIS Pro 3.7.1                              | Photographs                             | Architectural features, materials, condition, and transformation |
| Photogrammetry                                       | Local, Architectural       | Agisoft Metashape 2.0.2, Autodesk Recap Pro 2025                              | Point clouds, meshes, orthophotos, DSM  | Morphology and qualitative features of settlements and buildings |
| LiDAR survey (ALS/SLAM)                              | Territorial, Architectural | DJI Terra 3.6, Emesent Aura .10.2, CloudCompare 2.14, Autodesk Recap Pro 2025 | Classified point clouds, DTM/DSM        | Terrain, landscape, and built morphology                         |
| GNSS survey                                          | Territorial, Architectural | Emlid Studio 1.5, ArcGIS Pro 3.7.1                                            | Control points                          | Spatial reference and survey control                             |

#### 2.4. Preliminary Modelling and Semantic Data Structuring

Before the modelling process, it was necessary to design a semantic framework to integrate the various information components collected during the research.

In particular, the diachronic depth required some effort to achieve satisfying results. In fact, the data structure derived from existing sources—e.g., geoportals' data—is generally organised into single time thresholds; to overcome this obstacle and obtain diachronically deep data, the Historic Landscape Characterisation (HLC) approach was particularly useful. This methodology has been developed since the 90s in England within the field of landscape archaeology and is aimed at interpreting and classifying territories as outcomes of stratified historical processes [4]. HLC is based on a few fundamental principles: the understanding of landscape as a dynamic, continuously evolving system; the centrality of the diachronic dimension; the relevance of all assets; the classification of elements according to their character; and the organisation of information into homogeneous units. In the early 2000s, this workflow was implemented with GIS, enhancing the possibility to query and analyse the data [33,34]. The data structure is interesting because it allows linking spatial extensions to their character, organised across different time thresholds. By doing so, it is possible not only to observe the landscape's historical character but also to query the database to highlight changes.

This approach proved particularly consistent with the research objectives and served as a starting point for designing the workflow. To obtain a semantically unified model relating landscape and architecture within a single interpretative framework, this method has been extended to architectural objects. Therefore, each territorial and architectural unit was defined not only by its current characteristics but also by the historical processes that shaped its form, function, and evolution (Table 2).

**Table 2.** Semantic data structure for the diachronic implementation, which has been added as an attribute or parameter depending on whether it is in the GIS or BIM environment.

| ID                                                                          | BT 1                              | ST 1                            | ... | BT n                          | ST n                        |
|-----------------------------------------------------------------------------|-----------------------------------|---------------------------------|-----|-------------------------------|-----------------------------|
| Unique identifier associated with the object (parcel or building component) | Broad type of the first threshold | Sub type of the first threshold | ... | Broad type of the n threshold | Sub type of the n threshold |

To characterise these assets, the research first relied on historical cadastres and cartography, which allowed the structuring of information from 1722 onward—the *Theresian Cadastre*—, adopted as the earliest systematic reference for reconstructing territorial and settlement configurations. This kind of document plays a central role in the research, as it anchors the analysis in a relatively homogeneous and sufficiently dense documentary basis from which the principal transformations of both territory and built heritage can be reconstructed through subsequent updates. In detail, adopting this source allows consideration of the land parcel as the minimum landscape unit. By doing so, it allows for quite granular information about the historical evolution of the land and buildings.

The nature of cadastral and historical cartographic documentation further underscores the need for a methodological approach that can simultaneously address multidisciplinary, multiscale, transscale, and diachronic. These sources do not merely document individual buildings or land parcels but also record the relationships among settlements, land uses, infrastructure, productive systems, and environmental conditions across successive historical periods.

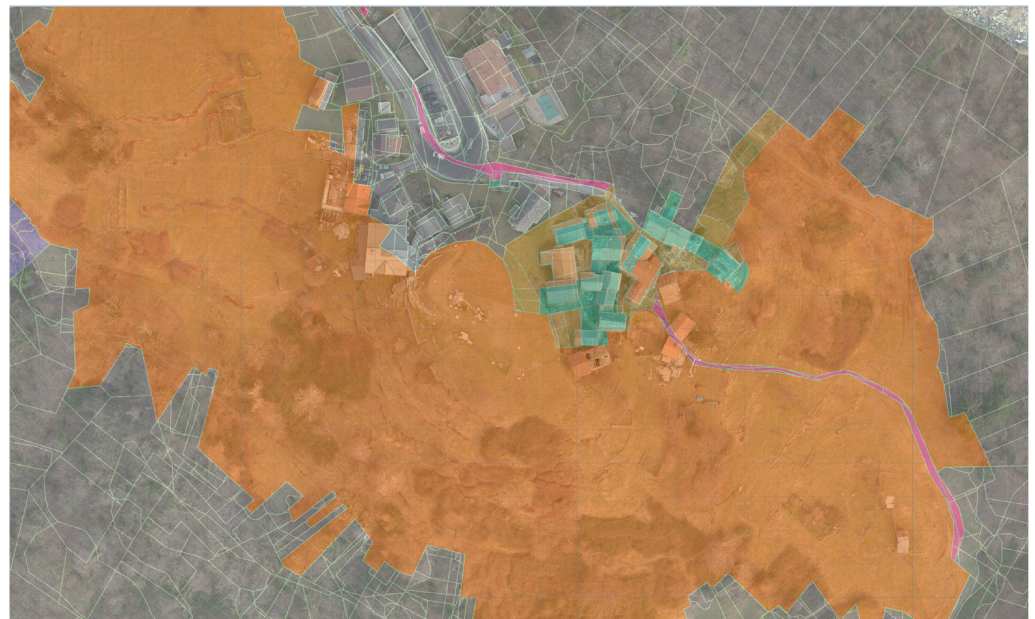
However, this kind of information does not preclude the development of more accurate investigations of buildings, which are necessary for interpreting the features of existing objects.

From a GIS perspective, the integration of the historical component was achieved by structuring temporal attributes and distinct thematic layers, organised according to chronological and qualitative criteria. In this way, the diachronic dimension is represented as a queryable stratification of information, capable of illustrating not only the current condition of heritage, but also its evolutionary trajectories (Figure 7).

While this phase is still primarily developed within a GIS environment, it establishes much more than a territorial database. The resulting semantic organisation provides the conceptual framework upon which the subsequent architectural modelling can be consistently developed, ensuring that buildings are interpreted as components of a wider territorial system rather than as isolated objects.

The HBIM modelling of the built heritage represents the natural continuation of the workflow. Unlike territorial information, which can be largely derived from existing documentary and spatial sources, architectural models must currently be generated almost entirely from scratch, as no open datasets providing this level of geometric and semantic detail are available.

The point clouds acquired during the fieldwork, therefore, constitute the primary geometric reference for the modelling process. Since the survey strategy only allowed documentation of the buildings' external envelopes, the information available for interior spaces and technological components remains limited. Consequently, some assumptions and simplifications were required, thereby preventing the full geometric and semantic granularity that would otherwise be achievable.



**Figure 7.** HLC method applied to the settlement of Civano. The image shows the comparison between the character of 1722 (vector layer, based on the Theresian Cadastre) and the orthophoto of February 2025 (raster layer, from the drone survey). Modifications can be observed, for instance, in the extension of agricultural lots (vivid orange), built environment (light orange), buildings (green), and routes (pink) (Elaboration: L.P.).

Beyond these survey-related aspects, further limitations derive from the intrinsic characteristics of current BIM environments. These workflows were originally conceived for the design and management of contemporary buildings rather than for the documentation of historical architecture. Consequently, irregular geometries, constructive stratifications, and historical transformations cannot always be represented faithfully through native parametric objects, often requiring modelling compromises and customised semantic structures.

Attention was therefore devoted to defining an appropriate level of geometric and semantic detail. Considering the research's territorial extent, its objectives, and the only possibility to investigate the exterior of buildings, the modelling adopts a LoD3, corresponding to simplified yet distinguishable building components.

Autodesk Revit 2025 was employed as the HBIM authoring environment for its mature modelling capabilities and robust interoperability via the Industry Foundation Classes (IFC) standard. In detail, this format was adopted because it provides a software-independent representation of both geometry and semantic information while ensuring interoperability between BIM authoring platforms and GIS environments.

The semantic organisation of the HBIM models was also carefully defined. Since BIM environments do not natively provide information structures specifically conceived for historical buildings, a dedicated parameter system—based on the HLC schema too—was developed to extend the principles already adopted within the GIS environment to the architectural scale. In addition to describing the components' physical characteristics, these parameters enabled the integration of chronological information, historical phases, conservation-related observations, and other attributes needed for subsequent integration.

The application of this semantic framework enabled the construction of a coherent information structure oriented not merely towards documenting heritage, but towards understanding the relationships and transformations that have shaped it over time. In this sense, diachrony does not simply represent an additional attribute of the information model. Still, it becomes one of its organising principles, supporting the interpretation of both landscape and architecture within a unified multiscale framework. This semantic

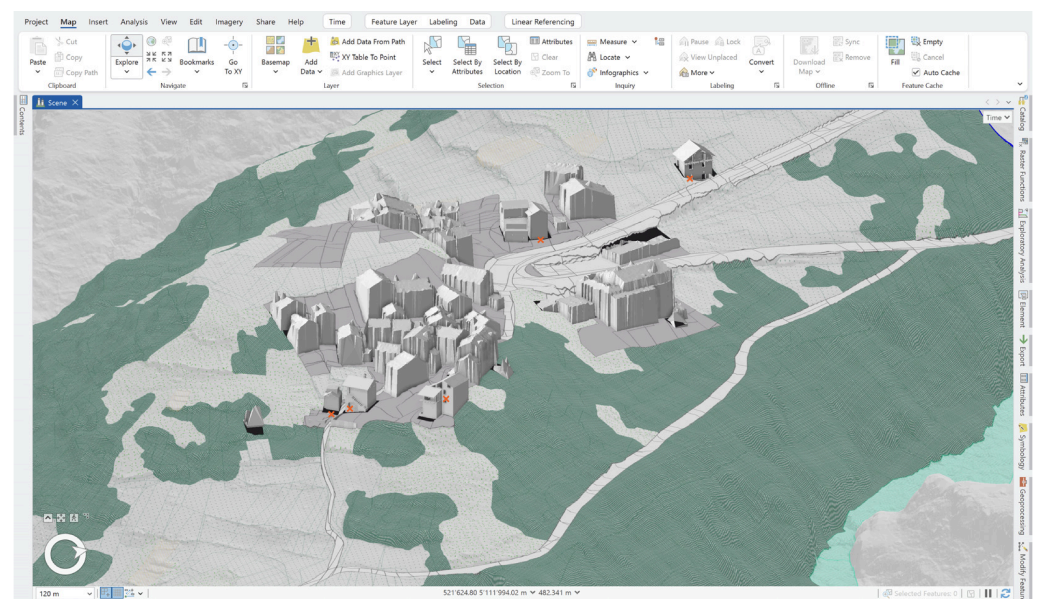


continuity also establishes the necessary basis for the subsequent integration of GIS and HBIM within a single information environment.

### 2.5. H-BIM-GIS Integration Strategy

Considering the outlined framework, this study examines the complementarity of BIM and GIS, adopting an explicitly pragmatic position. The objective is not to develop an optimal solution from the perspective of interoperability, but rather to evaluate the extent to which, and through which methods, it is now possible to construct an integrated environment that is effective, accessible, and replicable in real operational contexts. BIM-GIS integration is therefore interpreted as a progressive process of relating data, rather than as a complete fusion between models and standards.

From this perspective, priority was given to adopting consolidated, widely available tools, avoiding workflows that depend on complex conversion procedures or highly specialised software. ESRI ArcGIS Pro (version 3.7.1) was selected as the principal platform because it provides a mature environment for managing geospatial information, relational databases, and three-dimensional datasets, while supporting interoperability with BIM models. Within the proposed workflow, GIS serves as the central information infrastructure through which territorial and architectural data are organised, connected, queried, and progressively enriched (Figure 8).



**Figure 8.** The result of integration in ArcGIS Pro regarding the settlement of Civano. Buildings can be modelled in both BIM, with richer semantics and geometry (objects with the orange ×), and in GIS, yielding a simplified but more irregular result from the LiDAR point cloud (Elaboration: L.P.).

Preliminary tests were also conducted using Autodesk InfraWorks 2024, whose capabilities proved valuable for visualisation and infrastructure-oriented applications but were less suitable for implementing the relational information structure required by this research [11,12,35].

Thus, integration occurs through the construction of a relational system, in which the different entities—territorial and architectural—are connected through unique identifiers and shared data structures. This relational organisation builds directly on the semantic framework established in the previous stages of the workflow, ensuring continuity between territorial and architectural information. In this way, the integrated model derives from their coherent organisation within a common environment, oriented towards multiscale

querying and the construction of informational relationships between territory and the built environment.

All metric information is structured within the Italian reference system RDN2008/UTM Zone 32N (EPSG: 7791), ensuring direct correspondence with existing cartographic datasets and survey outputs, and enabling the integration of additional information within a multiscalar analytical framework. In this sense, the HBIM models were positioned within geographic space by aligning their origin points to the reference system.

From an operational standpoint, the integrated information system was developed by defining a relational data structure to organise and connect the different types of information collected throughout the research. The environment was implemented in ArcGIS using a geodatabase (.gdb), which served as the principal infrastructure for managing territorial and architectural data.

In this sense, the integration of GIS data required relatively limited additional processing, since territorial datasets were already compatible with the adopted geodatabase. The integration of HBIM models, by contrast, required more careful consideration of the exchange format and of the implications of transferring object-based architectural information into a GIS environment. Although ArcGIS Pro can import IFC files directly, the resulting objects remain organised according to the IFC schema's internal hierarchical logic. Consequently, the models can be visualised and individually explored, but their direct integration with the relational geodatabase and the development of advanced spatial analyses remain limited.

To overcome this limitation, a dedicated *IFC-to-Feature Class* workflow was adopted to convert IFC instances into GIS Feature Classes while preserving the semantic information required for the research. Through this process, architectural components became standard geographic entities with geometries and attributes fully manageable within the GIS environment. The various HBIM models were thus incorporated into a homogeneous relational structure consistent with the remaining territorial datasets.

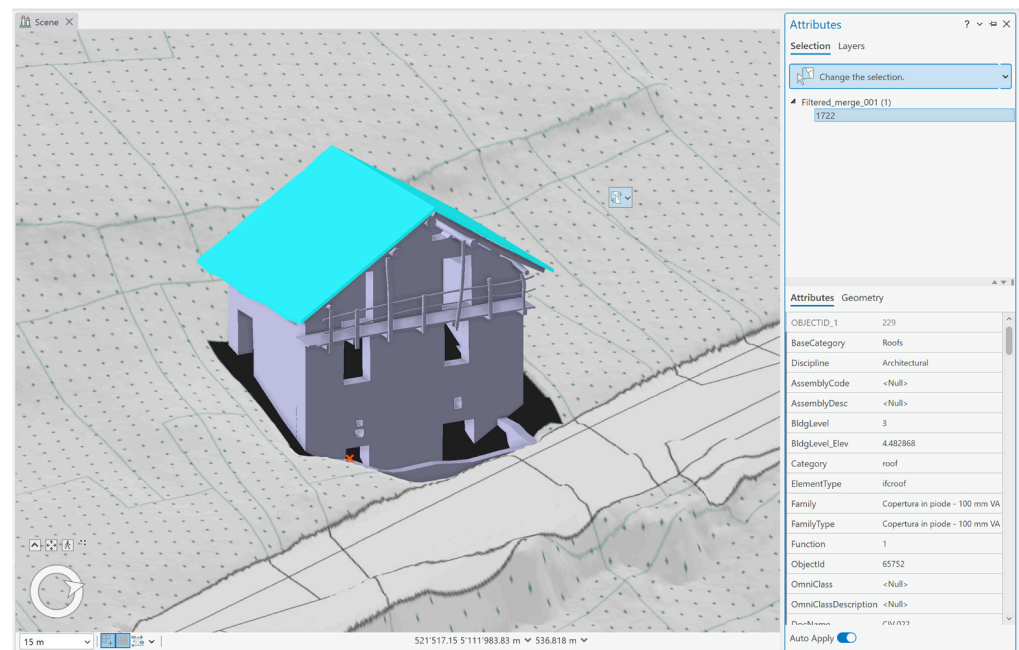
The resulting Feature Class constitutes a unified layer at the territorial scale containing the entities derived from the IFC files, within which spatial and attribute queries, relational operations, and thematic visualisations can be performed. Unlike native IFC objects, these entities can fully participate in the GIS environment's analytical capabilities, including relational joins, spatial analysis, thematic mapping, and geodatabase operations. The unique identifiers previously assigned act as a linking key between descriptive tables and the other datasets within the information system, thereby ensuring consistency between geometric representation and semantic content.

Therefore, the system's structuring enabled a significant reduction in the informational discontinuity between the territorial and architectural scales. Converting IFC instances into Feature Classes enabled the integration of architectural elements into the GIS environment as queryable geographic entities while maintaining semantic content consistent with the research objectives.

This approach enables the linking of the morphological, typological, and functional characteristics of buildings to territorial data on land use, infrastructure, settlement distribution, and environmental conditions. As a result, integrated multidisciplinary, multiscalar, transcalar, and diachronic analyses can be developed, enabling the interpretation of the built environment as part of a broader territorial system rather than as an isolated collection of structures.

The integrated environment also enables the performance of various analytical operations based on both geometric and semantic information. Spatial and attributive queries are possible, including typological classifications, thematic representations of conservation conditions, and comparative analyses of buildings, settlement systems, and the territorial

context. This makes it possible to develop a queryable and updatable knowledge framework oriented not only to heritage documentation but also to supporting planning and reuse processes (Figure 9).



**Figure 9.** Simple information query on an IFC to Feature Class converted object. The technical components of the BIM model remain readable and selectable within the GIS environment (Elaboration: L.P.).

Ultimately, this approach enables a balance between methodological rigour and operational sustainability. While accepting certain limitations in terms of formal interoperability between standards, it nevertheless enables the construction of an information system consistent with the objectives of the research and compatible with the operational conditions typical of marginal contexts. In this sense, the work constitutes an evaluation of the concrete possibilities for BIM-GIS integration currently applicable in territorial and heritage-related contexts, oriented towards defining realistic and transferable workflows rather than theoretically optimal but more difficult-to-implement solutions.

### 3. Results

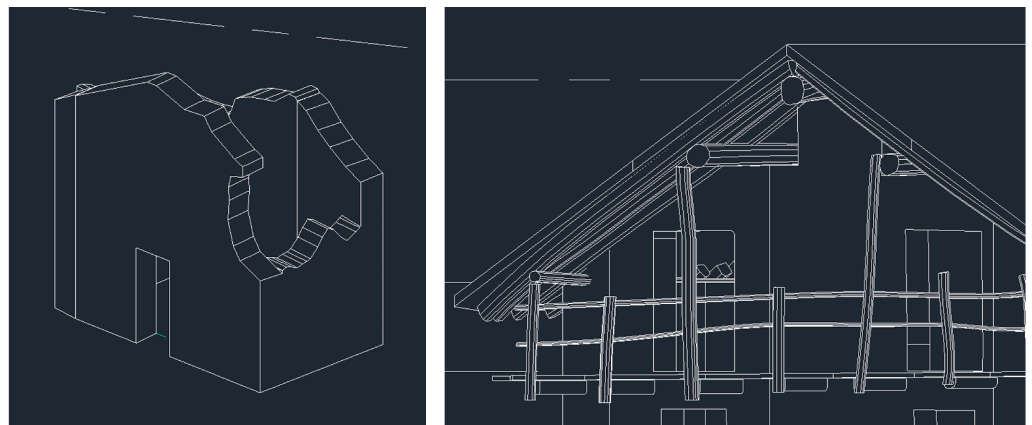
#### 3.1. Features of the Achieved Model

As demonstrated, the experimentation resulted in the construction of an integrated knowledge infrastructure capable of relating territorial and architectural data within a queryable, multiscalar, three-dimensional digital environment, in coherence with the methodological premises. More specifically, the developed system enables the organisation of heterogeneous information within a unified framework, allowing several components to be analysed in relation to one another.

From a territorial perspective, the environment integrates multiple layers of information concerning both the natural and anthropogenic components of the landscape. The territorial structure is described using Digital Elevation Models (DEMs), geological data, vegetation cover, hydrographic networks and water bodies, and information on land use, infrastructure systems, and settlement organisation. This makes it possible not only to reconstruct the spatial configuration of the territory but also to interpret the historical relationships between environmental, productive, and settlement components that have shaped its development over time.

Regarding built heritage, rural buildings and artefacts were modelled using HBIM procedures and measurements derived from photogrammetric and LiDAR surveys. This not only allowed for the integration of the geometric representation of buildings into the GIS environment, but also of information on their morphological, typological, and functional characteristics. Modelling activities involved both technical elements and the function of interior spaces, enabling buildings to be represented not merely as three-dimensional volumes, but as articulated spatial systems enriched with semantic information. At the current stage of the experimentation, HBIM implementation has been completed for a representative sample of buildings selected to test the proposed methodology. However, extending architectural modelling to the entire building stock would be the methodologically preferable approach for the research objectives. Such an extension remains feasible within the proposed workflow, though it would require considerably more effort given the time-intensive nature of HBIM generation.

The HBIM models developed during the experimentation were conceived not only as digital representations of selected buildings but also as methodological testbeds to exemplify and compare different modelling approaches and to evaluate their behaviour once integrated within the GIS environment, while achieving an overall Level of Detail broadly corresponding to LoD3 (Figure 10).

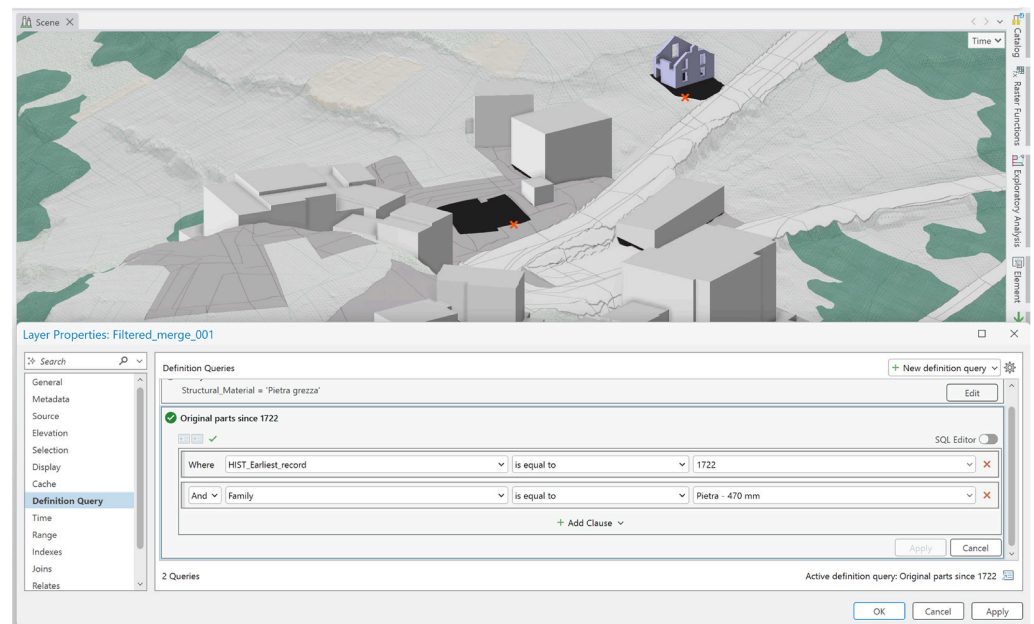


**Figure 10.** Comparison between essential and geometrically richer BIM models. In the first case, the modelling was developed solely in Revit, while in the latter, Rhinoceros was used for the structural framing and the balcony. In terms of semantics, no significant differences arise (elaboration: L.P.).

The experimentation also demonstrated the possibility of performing a broad range of spatial and semantic queries across the system. For instance, it is possible to analyse the historical stratigraphy of the settlements by filtering building components by construction date, which is, in most cases, approximate (Figure 11). Also, it is possible to investigate and compare the historical and current uses of the rooms, buildings, and surrounding areas. Again, the materials of building components can be queried to map the distribution of specific techniques. Thus, from these few examples, it is easy to imagine the breadth of all the possible fields of investigation.

The analytical potential of the environment depends directly on the quantity and quality of information associated with GIS and BIM datasets; in fact, the integration of diachronic information enables the reconstruction of settlement evolution and the comparison of permanence and transformation processes affecting individual buildings and territorial structures. From a compatible reuse perspective, this enables the reconstruction of buildings' original characteristics and functions and, consequently, provides more informed guidance on compatible interventions and transformation scenarios.





**Figure 11.** ArcGIS Pro also enables querying and representing complex combinations of attributes, as in this explanatory case (elaboration: L.P.).

In this sense, the developed workflow also proved capable of generating a wide range of outputs for both analytical and dissemination purposes. Alongside traditional GIS products—such as thematic cartography, quantitative and qualitative reports, and spatial analyses—the system enables the creation of three-dimensional visualisations that could also be disseminated through web-based storytelling platforms such as ArcGIS StoryMaps. This considerably broadens the environment’s applicability, making the heritage accessible not only for research and planning but also for communication, dissemination, and public engagement.

Overall, the experimentation confirms the feasibility of constructing an integrated H-GIS-BIM environment that relates territorial and architectural information within a coherent multiscalar knowledge framework, demonstrating the practical applicability of the proposed workflow for the documentation and interpretation of heritage in Inner Areas.

### 3.2. Accessibility of the Process and Integration Limits

Within the broad spectrum of BIM-GIS integration research, the proposed workflow can be positioned among those approaches that primarily address integration at the methodological. Rather than pursuing complete semantic and technical interoperability through highly specialised data models or custom middleware, the research investigates how existing software environments and established exchange standards can be combined to construct an integrated information system that is operational, accessible, and replicable. This perspective deliberately privileges practical applicability.

In fact, the entire process was developed using software environments widely employed in the AEC sector, thereby limiting reliance on complex conversion procedures or highly specialised tools wherever possible. This aspect is particularly relevant in the context of Inner Areas, where simple, economical, and efficient operational structures are fundamental.

Within this perspective, the proposed workflow demonstrates that a coherent H-GIS-BIM environment can be constructed using tools already established in academic and professional practices, thereby making the approach more readily transferable to operational contexts that may lack specialisation on these systems.

However, this does not imply that the proposed workflow is entirely independent of commercial software. Current BIM-GIS integration still relies heavily on proprietary platforms, which presently provide the most mature solutions for managing complex three-dimensional and semantic datasets. Nevertheless, the methodological framework proposed here is not inherently tied to specific software products and could be progressively adapted as more mature open-source or interoperable alternatives become available.

From the perspective of heritage reuse and planning, this aspect becomes particularly relevant. Through the relational organisation of information, the database enables the reconstruction and schematisation of the evolution of buildings, thereby supporting more informed evaluations of compatible interventions, reuse strategies, and the preservation of historically significant spatial and constructive features, while also incorporating planning constraints and municipal planning regulations into the evaluation process. In this sense, the integrated environment functions not only as a repository of information but also as an interpretative support system, assisting territorial and architectural decision-making processes.

However, the experimentation also highlighted several structural limitations—consistently with the existing literature—in both interoperability and the system's long-term sustainability. The direct conversion of IFC instances into Feature Classes enabled rapid integration of HBIM models into the GIS environment, making the information immediately queryable and usable for territorial analyses, thematic visualisations, and relational operations across datasets.

At the same time, this process transforms the BIM object into a substantially static entity that retains essential geometry and attributes while losing part of the parametric relationships and dynamic logic inherent in the BIM authoring environment.

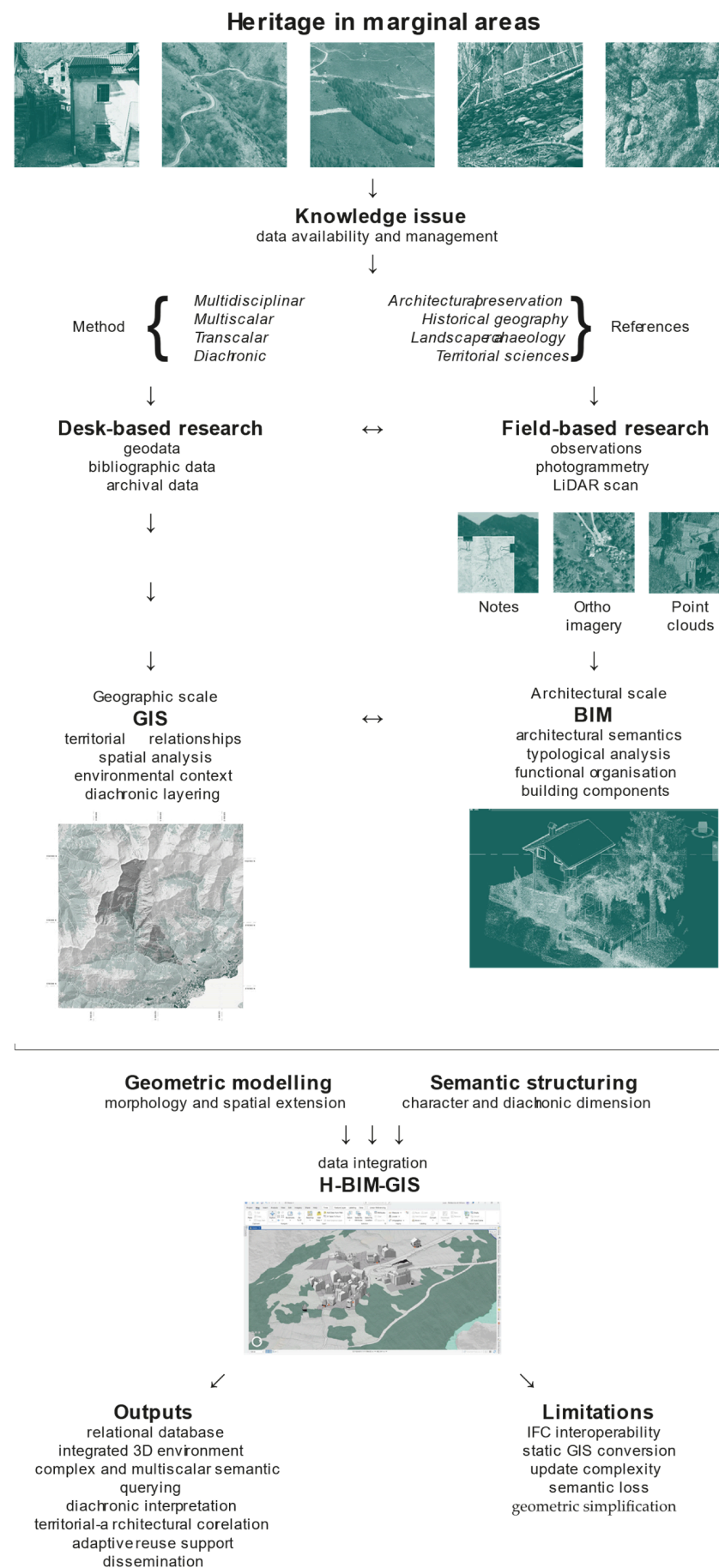
Consequently, the GIS dataset derived from the conversion process does not preserve a dynamic connection with the source IFC model. Any geometric or informational modification to the HBIM model requires repeating the entire export, import, and conversion workflow. This condition significantly affects update management, making iterative processes, continuous monitoring, and progressive heritage documentation considerably more demanding from both an operational and organisational perspective.

Additional issues concern the partial loss of semantic relationships originally embedded within the BIM model. Although the adopted workflow preserves sufficient information for territorial and architectural analyses, certain hierarchies and object relationships remain difficult to transfer into the GIS structure without more advanced mapping procedures. This aspect becomes particularly problematic in the case of historic and rural heritage, where pronounced geometric irregularities, layered transformations, and non-standardised construction systems characterise buildings.

The experimentation also demonstrated how the creation and maintenance of such integrated systems require considerable analytical resources. The study of diffuse historic heritage—to be properly effective—demands stratigraphic and diachronic investigations capable of reconstructing successive phases of transformation in buildings and landscapes. Consequently, the construction of the information environment cannot rely exclusively on automated procedures, but requires continuous interpretative work within the organisation, as well as the verification and updating of data.

In this sense, significant issues can arise not only during the initial implementation of the system but especially during its long-term maintenance, where tracking transformations and updating information are particularly resource-intensive.

The adopted workflow (Figure 12) should therefore be interpreted as a deliberate balance between technical rigour and operational sustainability. Although it does not eliminate the interoperability challenges that continue to characterise this domain, it demonstrates that a robust and coherent H-GIS-BIM environment can already be implemented using currently available technologies.



**Figure 12.** Diagram of the research workflow (images: L.P.).

## 4. Discussion

### 4.1. Integration Between Territorial and Architectural Scale

From the methodological point of view, this work demonstrates how H-GIS-BIM integration can mitigate the longstanding separation between territorial and architectural analysis in the domain of built heritage and, at the same time, improve the quality of knowledge in contexts where assets are scattered, as in this case.

From this perspective, the principal methodological outcome of the research is the construction of an information environment that relates data across different scales and domains while maintaining accessibility compatible with ordinary operational contexts. The conversion of IFC instances into Feature Classes enabled the integration of architectural elements into the GIS environment as queryable, georeferenced entities, thereby enabling a unified interpretation of the territorial and settlement system.

Such integration concerns not only the geometric dimension but, above all, the semantic one. Indeed, the possibility of associating buildings with information useful for further investigations enables the interpretation of heritage as a complex system of relationships, and the use of a product such as BIM, which is increasingly the basis for any intervention in the built environment, is highly advantageous.

In this sense, it is easy to understand the H-GIS-BIM environment as a knowledge infrastructure, intended not only to represent heritage but also to understand the processes that generated and transformed it.

However, the research confirms that the application of HBIM in contexts of diffuse historic heritage requires adapting the logics underlying BIM for modern and contemporary buildings. Dealing with morphologically complex objects such as historical buildings, modelling cannot be oriented exclusively towards geometric accuracy or the full parametrisation of elements. In such cases, geometric simplification and the reduction in parametric complexity should not be understood as limitations of the model, but rather as methodological choices functional to the construction of information systems that are more legible, queryable, and manageable.

Within this framework, the role of geometric simplification also emerges clearly as a conscious methodological choice. The research demonstrates how, in H-GIS-BIM integration processes oriented towards the construction of territorial knowledge, the informational and relational quality of data may assume greater relevance than highly faithful geometric representation. The integrated environment is therefore conceived primarily as a semantic and relational system, in which geometry serves as a supporting instrument for the organisation and querying of information, rather than as the ultimate goal of modelling.

In contexts such as Inner Areas, approaches excessively oriented towards geometric complexity or theoretically complete interoperability risk becoming operationally unsustainable. By contrast, the experimentation demonstrates that it is possible to construct sufficiently robust and effective information systems even with more accessible workflows, provided they are grounded in a coherent semantic structure and a clear definition of knowledge objectives.

Moreover, extending the diachronic approach to the architectural scale is central to the research. It makes it possible to introduce a coherent interpretative structure grounded in the reading of the relationships among character, form, function, and historical transformation, thereby bridging the gap between landscape and the built environment. This component is thus not treated as a simple additional attribute of the model, but rather as a structuring principle of the entire information system.



#### 4.2. Interoperability, Data Conversion and Workflow Limitations

The research operated at the workflow level, trying to bypass rather than directly address the issues of format interoperability. Despite the results achieved, interoperability between BIM and GIS remains a core issue in the construction of integrated information environments. The difficulties encountered do not concern technical compatibility between software and formats alone, but rather involve the very nature of information models and the different logics by which the two domains structure and interpret data.

As previously noted, the objects derived from the IFC are converted into static entities that retain essential geometry and attributes while losing some of the parametric and hierarchical relationships characteristic of the authoring environment. This aspect is particularly critical in contexts where the information system is intended to support iterative processes, continuous monitoring, or the progressive updating of heritage information.

The loss of data dynamism reveals one of the principal limitations of current application-based integration workflows: while the resulting GIS environment proves highly effective for querying, thematic representation, and spatial analysis, it is less suitable for the continuous management of the architectural model.

These considerations also clarify why the proposed environment should not be interpreted as a Digital Twin (DT). Although the system enables the integrated organisation, visualisation, and querying of multiscalar heritage information, it does not maintain a continuous bidirectional synchronisation between the BIM and GIS domains, nor does it incorporate real-time data streams, dynamic simulations, or automated updating mechanisms that characterise DT frameworks, indeed. Rather, the proposed environment should be understood as a structured digital knowledge infrastructure supporting documentation, interpretation, and decision-making through periodically updated information.

Additional criticalities concern the transfer of the semantic component. Although converting to a Feature Class allows maintaining an information level consistent with the research objectives, some of the original relationships between BIM objects remain difficult to translate into the GIS structure without more advanced mapping procedures, like the ETL ones. This becomes particularly evident in the case of historic heritage, where building elements cannot be reduced to standardised families and instead present a high degree of geometric, functional, and constructive heterogeneity.

From this perspective, workflows based on IFC-to-CityGML conversion would enable a more rigorous management of interoperability, enabling a more coherent semantic structuring of three-dimensional territorial models. Such approaches enable a more systematic mapping of attributes, classes, and information relationships, thereby improving the preservation of the semantic component during transitions between domains. However, the experiments demonstrate that these procedures entail a significant increase in operational complexity. The use of ETL tools, the need to define specific mapping rules, and the management of transformations across different standards require specialised expertise and resources. However, this issue cannot realistically be resolved within Inner Areas themselves, as it requires broader, more structural action at the national level, including the development of shared standards, interoperable digital infrastructures, institutional coordination, and specialisation.

Furthermore, even with advanced workflows, data transformation still involves reprocessing geometries and a partial redefinition of the original information structures.

In this sense, the research highlights the need to interpret interoperability not as an absolute goal of perfect correspondence between models, but rather as a balance between informational quality, operational sustainability, and knowledge-related aims. The adopted workflow, therefore, constitutes a conscious compromise, oriented towards prioritising

accessibility, replicability, and analytical capacity over the complete preservation of the parametric logics inherent to the BIM domain.

More broadly, the criticalities that emerged suggest that the construction of H-GIS-BIM environments for diffuse heritage requires not only technological advancements, but also a methodological reflection on the nature of historical and territorial data. In contexts characterised by strong stratification and incomplete documentation, the objective must also focus on constructing information systems that support complex interpretative processes while maintaining a balance among detail, legibility, and management sustainability.

#### *4.3. Applicative Perspectives and Method's Transferability*

These issues aside, the research also demonstrates the possibility of developing a methodological approach that integrates territorial and architectural data into a coherent, multidisciplinary, multiscalar, transcalar, and diachronic information system. The centrality of the relational dimension of data enables moving beyond a purely descriptive interpretation of heritage, orienting the system towards interpretative and operational purposes.

The developed approach is relevant in contexts characterised by ordinary and diffuse heritage, such as Alpine rural areas, where the fragmentation of information and the lack of structured knowledge tools often pose major obstacles to planning, conservation, and reuse. In such contexts, the possibility of constructing integrated information environments through relatively accessible workflows constitutes a strategic element, especially in situations characterised by limited economic and technical resources.

The research further demonstrates how GIS can assume a distinct role beyond its traditional one in heritage documentation. Within the proposed workflow, in fact, it serves as the informational framework in which data from different scales and domains converge. From this perspective, the geodatabase is conceived as a relational structure that supports complex queries, comparative analyses, and transcalar interpretations of heritage.

From a practical perspective, the proposed method presents potential for transferability to other marginal contexts characterised by similar conditions: discontinuous data availability, diffuse heritage, strong relationships between the built environment and territory, and the need to support processes of reactivation or territorial planning. In this regard, the possibility of implementing workflows based on widely used software and operational procedures that are not excessively specialised is one of the most significant aspects of the research.

Nevertheless, several issues remain and require further investigation. In particular, the absence of dynamic links between BIM models and the GIS environment limits the ability to continuously update the information system. At the same time, issues related to semantic interoperability highlight the need to develop more advanced mapping procedures across different standards. Improvements in the field of matching IFC and CityGML standards, and their implementation with diachronic information, can provide significant results for the development of this kind of tool.

In the future, further developments could also focus on implementing more automated workflows in architectural and territorial surveying, using intermediate semantic models to improve the evolution of data management and enhance the operational sustainability of the process.

An interesting aspect that warrants further investigation is also the relationship between this kind of digital infrastructure and DTs. Still, given the relative ease of creating these environments, they could serve as intermediate steps toward future implementation. In fact, given the complexity of the sources and the heritage itself, it is reasonable to imagine a phase between collecting information and creating an effectively interoperable system.

## 5. Conclusions

This research addresses the problem of constructing integrated knowledge systems for built heritage located in marginal and inner territories, contexts in which architectural artefacts, settlement structures and landscape configurations are deeply interconnected and cannot be effectively interpreted through sectoral or mono-scalar approaches. Within these areas, the progressive weakening of traditional socio-economic systems has not only generated phenomena of abandonment and degradation but also a broader loss of intelligibility in the relationships among territory, the built environment, and historical functions.

Starting from these premises, the study proposed a methodological framework grounded in multidisciplinary, multiscalar, transcalar and diachronic principles, aimed at overcoming the persistent separation between territorial and architectural analysis. In this perspective, the integration of HBIM and GIS was not interpreted as a purely technical objective but as a means of constructing coherent relational environments that connect heterogeneous information across different spatial and temporal scales.

The test conducted in Dosso del Liro demonstrated the possibility of developing an integrated digital environment through workflows that remain compatible with ordinary operational contexts and with the limitations often characterising inner areas. The adoption of ArcGIS Pro as the central informational framework, combined with the conversion of IFC instances into Feature Classes, enabled the integration of architectural and territorial data within a shared relational structure, supporting spatial queries, semantic analyses and diachronic interpretations of the built heritage.

At the same time, this research highlights several critical issues that still characterise BIM-GIS interoperability but that can be methodologically bypassed. In particular, transforming IFC models into GIS entities results in a partial loss of parametric relationships. It prevents the establishment of a dynamic connection between the BIM source model and the integrated territorial environment. More advanced workflows based on IFC-to-CityGML conversion would allow a more rigorous semantic interoperability, but currently require levels of technical complexity and operational resources that are often incompatible with the realities of marginal territories.

One of the main outcomes of the research, therefore, concerns the definition of a pragmatic balance between technical rigour and operational accessibility. The study suggests that, in the context of widespread, ordinary heritage, the effectiveness of integrated H-GIS-BIM environments depends less on achieving complete interoperability and more on structuring coherent semantic frameworks that support interpretation, management, and planning processes.

In this sense, the proposed methodology should not be interpreted as a definitive solution to BIM-GIS integration, but rather as an operational assessment of currently applicable strategies for constructing integrated knowledge systems in marginal contexts. The approach demonstrates how relatively accessible tools and workflows can nevertheless support the development of structured, interrogable informational environments capable of reconnecting architectural and territorial dimensions that are traditionally treated separately.

Future developments should focus on improving the workflow's extendibility, semantic interoperability, the automation of phases such as data collection, modelling, and updating procedures, and strengthening the dynamic relationship between BIM models and GIS environments. At the same time, further research should continue to investigate the role of integrated digital systems not only as tools for documentation but also as cognitive infrastructures capable of supporting long-term conservation, reuse, and territorial planning strategies in fragile and marginal heritage contexts.

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