AN INTEGRATED HBIM-GIS DIGITAL ENVIRONMENT FOR HERITAGE PRESERVATION AND ENHANCEMENT IN THE INNER ITALIAN TERRITORY

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ABSTRACT:

Depopulation in Italy is causing the marginalization of several inner territories and municipalities, with consequences for the preservation of different levels of heritage. The Italian National Strategy for Inner Areas (SNAI) aims to address these issues, but in some cases, the policies undertaken are not effective enough to improve development. In this context, the integration of Historic Building Information Modeling (HBIM) and Geographic Information System (GIS), as a potential solution in the enhancement of knowledge, information, and project management, could be an important resource to lean on. To investigate this aspect, the municipality of Dosso del Liro in the Northern part of Lake Como (Lombardy) has been chosen as a case study, based on its marginality and its territorial variety. The research methodology involves a combination of field data collection, bibliographical and archival investigations, database research, and digital recording of heritage, with the purpose of modelling and analyzing the territorial context on different aspects and at different scales. Precisely, multi-disciplinarity and multi-scalarity (but also multi-temporality) are the key points for the HBIM-GIS modelling. Thus, trying to integrate and interpret in this innovative way the information acquired, the research aims to investigate the possibility of improvement for the creation of effective strategies and projects in the Inner Areas. The idea, in fact, is that with an increased knowledge and awareness of the heritage, the requirements for the design phase will be better in sight, and the quality of the intervention will be increased.

1. INTRODUCTION

1.1 The concept of Inner Area and policies adopted

The phenomenon of depopulation has led to a significant marginalization of certain areas in Italy, the so-called *Inner Areas* (Fig. 1).
Despite the phenomenon's heightened intensity since the Second World War, aligning with substantial industrial and economic development (Panta and Detti, 2019), this is not a novel concern within the Italian context. In several regions of the country, demographic decline has ingrained itself over time, assuming even a historical connotation.
The reasons for this phenomenon can all be traced back to the search for better living conditions and quality of life.
With the abandonment of these regions and a consequent reduction in human presence within them, social costs have increased, leading to a series of significant negative consequences. These are strictly linked to the problem of territorial degradation (Fig. 2), causing hydrogeological instability (a current issue in the Italian landscape), loss of biodiversity, loss of landscape, historical, architectural, and cultural capital, the latter also understood its sense of traditional knowledge (1).

Figure 1. The villages in the Italian Inner Areas can be very remote, lacking in services and in proper communication routes that allow for adequate connection with the main centres (image L. Pozzoni 2023).

To address this problem, the Italian National Strategy for Inner Areas (SNAI) was established through the Agency for Territorial Cohesion. Its main goal is to *reverse and improve demographic trends* (2), closely related to the mentioned social costs.
In the document related to the Partnership Agreement 2014-2020, the context of Inner Areas – understood as *areas*

(1) Intended as an intangible cultural heritage based on knowledge, skills, and practices of a specific community. Agenzia Nazionale per la Coesione Territoriale 2017. Accordo di Partenariato 2014-2020, Strategia nazionale per le Aree interne: definizione, obiettivi, strumenti e governance, Section 1A, p. 15
(2) Ivi, p. 6

significantly distant from centres offering essential services (education, health, and mobility), rich in important environmental and cultural resources, and strongly diversified by nature and as a result of centuries-old anthropisation processes (3) – is objectively defined by introducing an accessibility index based on the distance in minutes from places providing essential services.
Five classes can be distinguished, consisting of service centres, belt areas, intermediate areas, peripheral areas, and ultra-peripheral areas. The latter three, in particular, are those that imply belonging to an Inner Area.
To achieve the ultimate goal of reversing and improving demographic trends, SNAI aims to catalyze the creation of preconditions for economic development (understood as guaranteeing access to the essential services of health, education, and mobility). This will be followed by a second category of actions with particular reference to the protection of the territory and the enhancement of natural and cultural resources.
In this sense, it is crucial to have in-depth knowledge of the landscape and architectural heritage, in relation to the countless local specificities that it is possible to encounter throughout the peninsula. This specificity is one of the factors that is somehow making the initiatives – undertaken in various regions – less effective, as they tend to be too general and therefore not suitable for individual cases.
This is compounded by the objective difficulty for small local administrations, which often struggle in the ordinary management of the community, lacking efficiency in dealing with situations such as participating in calls for proposals.
At the end of the first seven-year period 2014-2020 of the Partnership Agreements, and now well into the new one, 2021-2027, the overall situation highlights how much still needs to be done and how much can be improved.

Figure 2. The marginalization process in the Inner Areas leads to the loss of heritage, as happens with these rural buildings in the Italian Alps (image L. Pozzoni 2023).

1.2 Cultural landscape and territorial complexity

The Partnership Agreements 2014-2020 are very clear regarding the territorial or cultural specificities that can be identified among the regions of the Italian territory. These specificities arise from the great diversity of landscapes that has developed over the centuries due to numerous factors characterizing different parts of Italy. These factors include climate types, morphology, societies that inhabited specific areas, and more.

(3) Ivi, p. 5

For a heritage-related study, given the high interconnection at various scales, it is advisable to adopt a landscape-oriented approach.
The concept of landscape, by definition, is not only connected to the natural aspects of the territory but also linked to the human activities taking place and their mutual interrelations (4).
Thus, complexity emerges even in areas that, at first sight, may seem simple.
So, this aspect can be described as a fabric of physical, environmental, social, and economic elements, where their dynamics and interrelations determine the characteristics of a place.
This complexity is due to the presence of intricate geographic configurations, diverse ecosystems, demographic dynamics, infrastructural networks, cultural heritage, and multiple human activities. Consideration of temporal factors is also crucial, as these relations evolve over time, influenced by natural or anthropogenic changes (Fig. 3).

Figure 3. Agricultural activities have a relevant impact on the aspect of the rural landscape, that depends mainly on the types of cultivation and on the organisation of properties (image L. Pozzoni 2023).

Therefore, to successfully systematize all the characteristics that emerge in this territorial complexity and gain a clear understanding of the factors influencing the context, it is necessary to develop a thorough analysis leading to effective comprehension. However, this does not always occur efficiently in revitalization projects within the context of Inner Areas.
The significant challenge lies in developing an adequate level of knowledge that is both multiscale and multidisciplinary, allowing for the simultaneous consideration of multiple factors.

2. HBIM-GIS INTEGRATION: AN OPPORTUNITY TO IMPROVE KNOWLEDGE, INFORMATION AND PROJECT MANAGEMENT IN THE CONTEXT OF INNER AREAS

2.1 Brief introduction on BIM-GIS integration

The theme of BIM-GIS integration is highly relevant in today's scientific landscape. With an increasing number of studies and applications (as shown in Zhu et al., 2018), the potential of such a combination is being explored, promising significant benefits across various sectors.
Framing the topic, it is possible to define BIM, *Building Information Modeling*, as a system that allows for the efficient

(4) Regarding the definition of landscape, the references have been both UNESCO's Cultural Landscape Handbook (Mitchell et al., 2009) and the Italian Decree 42/2004, art. 131.

management of a building system (or small-scale infrastructure) in its entirety. It enables control over the entire process, starting from architectural design, through structural, technological, and systems design, to the management of the building throughout its life, including scheduled maintenance plans, etc.

Models of this kind serve as central hubs where crucial information such as costs, timelines, environmental and sustainability data, as well as geometric and technical data, are integrated. This centralization of information enables different stakeholders involved in the building's lifecycle to collaborate more efficiently and make informed decisions.

The greatest strength of this system lies in transcending the mere visual representation of buildings, evolving towards a multidimensional data repository. Beyond geometry, the BIM model incorporates detailed and interconnected information about physical characteristics, materials, energy performance, and systems. This integrated approach allows for the comprehensive management of the construction project, incorporating financial data, timelines, and post-construction maintenance information. In this way, a geometric entity representing, for example, an elevation element, can associate information about materials, their thermal properties, structural resistance, fire resistance, and so on.

BIM is not limited to new constructions but can also be effectively applied to existing objects, in which case it is referred to as HBIM, or *Historic BIM*.

However, as the scale decreases, the effectiveness of this design process diminishes due to several factors such as, for example, the curvature of the Earth, which is not considered in a local reference system like the one used in the BIM. In this case, the Geographic Information System (GIS) comes into play allowing, like BIM, the management of various types of information, but at a cartographic level. Also in this context, there is a convergence of geometric and attribute data to provide a comprehensive and informative representation. In fact, in GIS spatial geometry is associated with attribute data that provides detailed information about represented geographic phenomena. For example, when representing a building or a structure in cartography, in addition to a georeferenced geometry, it is possible to associate data like, for example, its use, construction date, materials used, sustainability information, and so on.

This integrated approach allows for a deeper understanding of the geographic context, facilitating complex analyses and informed decisions. GIS becomes a powerful tool when geometry and attributes are carefully connected, offering a clear and complete view of the geographic landscape and its various components.

In light of this brief introduction, it is easy to perceive the points of contact between these two tools, making them almost complementary. While BIM essentially operates at an architectural or single infrastructure scale, GIS operates at a territorial level. Effectively integrating these systems could present a great opportunity for conducting more extensive investigations where contexts require multi-scale and multi-thematic knowledge.

However, despite numerous studies in this sense, complete integration between the two systems has not yet been achieved and is essentially linked to a fundamental problem: the difference in computer language on which BIM and GIS are based, namely IFC (*Industry Foundation Classes*) and CityGML (*City Geography Markup Language*), respectively. From this, four main issues arise, related to the conversion of the Levels of Detail (*LoDs*), geometric data (due to different kinds of representation), semantic data (due to different ontologies between BIM and GIS attributes), and reference systems (local in BIM and geographical in GIS) (Zhu and Wu, 2022).

Considering these issues, many studies have highlighted the possibility of bypassing them through the coordinated use of existing applications. Just to mention a few examples in this direction, it is possible to refer to the study developed in the historical context of Sondrio (Italy), where the combined use of Autodesk Revit and Autodesk Infraworks allowed the adoption of a multi-scale approach for the heritage, with the possibility of integrating a large amount of data (Barazzetti, 2021). Similarly, the UNESCO site of San Pietro al Monte (Italy) has also been studied, with the combination of several kinds of information in the same suite of software (Barazzetti and Roncoroni, 2021).

Another interesting case is the *Interreg Main.10.ance*, where an HBIM-GIS approach has been used to improve the management of planned maintenance on the Sacri Monti, religious structures in Northern Italy and Canton Ticino (Switzerland). In this context, a user-friendly application based on databases (designed to be accessed and used by different experts in the field of conservation) helped to enrich the information on the heritage at several scales and on several aspects (Colucci et al., 2022; Colucci et al., 2023).

2.2 Goals of the research and potentialities in the application of HBIM-GIS systems to the context of Inner Areas

In light of the preceding considerations, this research aims to address a question: considering the challenges faced by many local administrations in Inner Areas and aspiring to sustainable development not only in terms of resources but also in the respect and conservation of the landscape and architectural heritage of these territories, is it possible to harness the technological potentials emerging in the integration of HBIM (Historic Building Information Modeling) and GIS (Geographic Information System)?

By working in this direction, the primary goal would be to fulfil the requirement of multiscale and multidisciplinary approaches, as referred to in Paragraph 1.2, with the added benefits of enhanced information management efficiency and synthesis. So, a dynamic tool aimed to allow the expansion and correlation among the various fields of study.

This applies to both the preliminary processes of understanding and the subsequent phases of design and intervention.

Given the current state of territorial strategies, the separation between territorial analysis and small-scale analysis often persists due to impermeability between large and small-scale studies, but also between the contributions of different experts. This poses a significant risk of information loss among them, leading to inefficiencies in managing existing assets and proposing new initiatives.

In this sense, the digital environment here imagined has the purpose of allowing easy storing, access, and visualization of multiple territorial data, which should also be easy to query.

3. METHODS

3.1 Investigation strategies

The research started with a thorough analysis of the methodology to explore the aforementioned theme, focused on better grasping the previously outlined territorial complexity. The topic of inner areas is often associated with rural contexts, sometimes territorially extensive. This implies the need for a method that should not be only analytical but also capable of interpreting both horizontally (across multiple disciplines) and vertically (across various historical thresholds) the characteristics of the places.

For these purposes, a keen interest was directed towards the theoretical and practical aspects of topographic surveying (e.g., Bertelli, 1895) and historical geography (e.g., Moreno, 1990).
Hence, the research journey assumed a dual nature: on one hand, the direct observation and collection of field data, and on the other, a series of indirect bibliographic and archival investigations aimed at complementing the acquired information.
However, these two categories of investigation are neither sequential nor compartmentalized; they proceed nonlinearly as the territory is studied.

3.2 Selection of a case study

Before proceeding with the implementation of the outlined approach, it was necessary to define a suitable case study. Aligning with the theme of Inner Areas, the initial judgment index was the classification of Italian municipalities performed by SNAI.
From among the diverse regions, the sample area selected was the *Alto Lago di Como and Valli del Lario* (5). This territory has undergone the effects of depopulation for ages, due to its distance from the cities and, notably, due to a marked inefficiency in communication and transportation systems.
In this context, the municipality of *Dosso del Liro* was identified, being a village with a population decreased from eight (1911) to two hundred (2023) inhabitants (6) in the north-western part of Lake Como.
This location, with its classic alpine connotation, was chosen not only for its affiliation with this marginalized context but especially for its significant territorial variety. The surface area (covering the valleys *del Liro*, *del Dosso*, *di Camedo*, and *d'Inferno* with a total of 23.5 km^2) and the altimetric range (from 500 to 2500 meters above sea level) influence the land use characteristics. The territory assumes, in fact, different features from the agricultural, urban, and architectural perspectives.
Due to varying climatic conditions dictated by the mountains, these differences arise from the need to adapt to seasons, exploiting, especially in the past, all the opportunities that the land had to offer.
Consequently, in connection with this periodic use, four main types of settlements are observed: the valley village (with more continuous habitation and characterized by a more significant urban system), the *maggengo* (a seasonal mountain settlement used for pasture between spring and summer and in autumn, a sort of middle station), the *alpe* (the high station, inhabited only in the warmer periods), and the *avert* (a subcategory of the alpe that includes high-altitude pastures, frequented only for few weeks a year) (Agostini, 1973).
This significant diversity of the territory corresponds to a substantial presence of landscape and architectural heritage, highlighting (once again) the complexity of seemingly simple contexts.
Following a preliminary phase of understanding the place, the recurrence of certain types of settlement within homogeneous altitude ranges has been noticed. So, it was decided to focus, for the time being, on the areas shown in Fig. 4, which are displaced along a main ridge that climbs from 500 to 1500 meters above the sea level. Working in this sense, it is possible to understand the behaviour of the HBIM-GIS model with a significative selection of spots, that synthesize the entire municipal surface.

(5) Agenzia per la Coesione Territoriale, 2018. Strategia d'area Alto Lago di Como e Valli del Lario.
(6) ISTAT census.

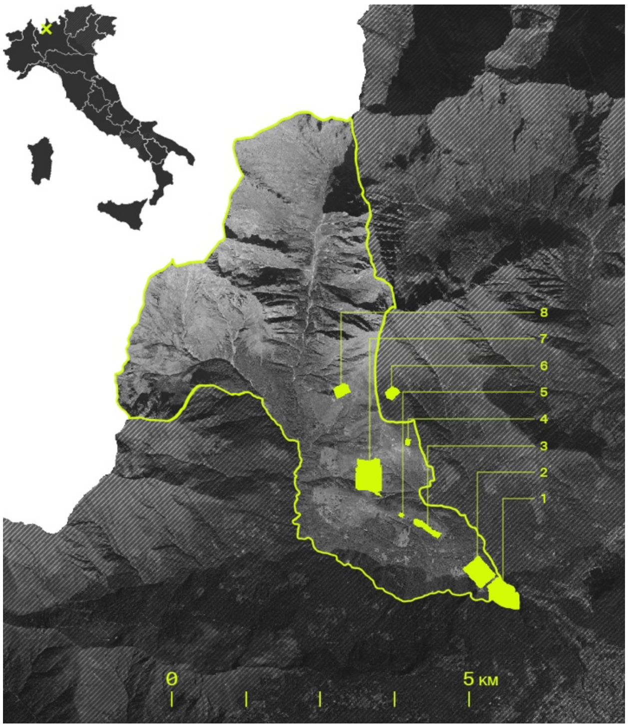

Figure 4. Geographical framing of the municipality of Dosso del Liro and the surveyed areas highlighted in yellow (1. Civano, 2. Dosso del Liro, 3. Prennaro, 4. Alpetto di San Carlo, 5. Sortaiolo, 6. Alpe Melbino, 7. Piaghedo, 8. Alpe Parod).

3.3 Bibliographical and archival investigation

It has been mentioned that the research has been divided into a stage on books and another one in the field.
The first was developed with particular consideration to the depopulation phenomenon. Thus, being an economic and political issue, the focus of bibliographic and archival research has specifically turned towards sources such as government records and cartography. Chronicles and historical territorial descriptions were additional fields in which to search for other information.
Particular attention has been given to historical land registers (and related reports developed from the 18th century onward), along with economic-agricultural surveys produced for the Italian governments from the mid-19th century (e.g., Jacini, 1854). These are complemented by additional studies that have helped to complete the overall picture.
It should be noted that, within the scope of this research and the considered case study, the starting point threshold was set at 1722. This date has a specific reason, as it coincides with the drafting of the first detailed cartography, the so-called *Teresian Cadastre*. Having an interest in reconstructing the evolution of the territory up to the present with a certain level of detail, understanding past land uses and activities is a fundamental step.
Therefore, by basing the historical component of the research on these two main categories of sources (bibliographic and archival), it is possible to achieve good accuracy in both the macro-context image (where bibliographic material provides the greatest contribution) and the micro-context (where, on the contrary, most credit goes to cadastral information and archival documents). In this way, the overall management of the state and events on individual parcels find correlation with each other.

3.4 Database research and open data

The research has not only focused on, so to speak, traditional archives but also digital ones were inspected. These sources, which are available online, were used to primarily verify the presence of cartographic data (vector and raster), as well as historical images and statistical data on the population of the object of investigation.
Databases at various levels (provincial, regional, national, and even international, as Fig. 5 demonstrates) provide indeed a significant amount of information on a good number of topics. A thorough analysis of datasets and data services provided and provides a better understanding of what additional information should be acquired for a better comprehension of the landscape studied.
Moreover, an important aspect of this phase, regarding spatial data, has involved the search for material that has been created within the INSPIRE Directive. This operation aims to the obtainment of information that is as interoperable and usable as possible across different fields, allowing to widen the range of applications.

Figure 5. Comparison between the orthophoto from August 18th, 1954 (source ©swisstopo) and the UAS orthomosaic of August 31st, 2023 of the little settlement of Civano. In this case, it is interesting to observe the massive change in the land use, that passed from vineyards and orchards to mainly fallow fields and woods. The built environment, on the other hand, remained almost the same, with few additions and several abandonments.

3.5 Digital recording of the heritage

Increasing the knowledge and the awareness of the investigated area, however, also requires a validation in the current situation. What type of data is most suitable for approaching this theme? Recognizing the potential of HBIM and GIS for studying these areas, it is essential to understand what can be used to develop models in this regard. Of primary importance are point clouds, which three-dimensionally represent real-world objects such as buildings, infrastructure, and terrain.
In addition to this, there is the opportunity to investigate land and structures with images that may range from the visible spectrum to bands not perceptible by the human eye. This allows for an extended field of inquiry, delving into aspects such as underground preexistences, the classification of vegetation types and health (particularly important in agricultural contexts), and so forth.
Technological developments in recent decades have made available numerous techniques and tools, that can be effectively employed to obtain these kinds of information. This leads to another research question: what is fundamental in the study of Inner Areas?
The fields of investigation were essentially three: laser scanning, photogrammetry (both terrestrial and aerial), and remote sensing.
Firstly, it was observed that these technologies work well at different scales, and there is significant complementarity among these digital recording systems.
Laser scanning, one of the classic methods for collecting spatial information in three dimensions, was tested with traditional stations (manually displaced during acquisitions), SLAM instruments (Simultaneous Localization and Mapping) and LiDAR tools (mounted on UAVs, Unmanned Aircraft Vehicles). The significant difference between these categories lies mainly in the density of point clouds: while the former provides more accurate and denser data, the second (especially, whose output is shown in Fig. 6) and the third provides an advantage in terms of survey time, which is drastically reduced. LiDAR on drones, furthermore, has the advantage of detecting large land extensions and obtaining more returns, which can be used, for example, to penetrate the vegetation barrier and record the ground surface.

Figure 6. Point cloud of the village of Civano obtained with a SLAM LiDAR.

Some techniques have been compared also regarding photogrammetry, balanced according to the field of application. On one hand, common cameras (such as the Sony A7III with 35 mm optics) were manually employed to survey small objects with characteristics of significant cultural interest. These included erratic boulders with rock engravings (Fig. 7.1) and architectural artefacts with details like graffiti and decorations.
On the other hand, drones with different kinds of cameras were subject to performance and image quality analysis, particularly the *DJI Air 2S* and the *DJI Mavic 3E* (Fig. 7.2-7.3). In addition to aspects related to sensors and lenses (which, however, for the purposes of mapping on a relatively small scale, could be considered somewhat negligible), the difference in the use of these drones essentially lies in the ability to use a precision GNSS antenna directly mounted on the second model. This allows georeferencing the survey in both RTK (Real Time

Kinematic) and PPK (Post Processed Kinematic), achieving centimetre-level precision in the position of the camera locations. In the absence of this component, georeferencing must be performed through the placement of GCPs (Ground Control Points), whose coordinates must be acquired with an additional GNSS antenna.
In these terms, the pros and cons generally balance each other. In both cases, it is possible to create a flight plan with native or third-party applications, and through them it is possible to manage the value of GSD (Ground Sampling Distance). It is undeniable that, with a larger sensor, the flight time for shooting decreases using the same focal length.
The significant difference, however, is that without integrated GNSS, the survey is slower, caring to manually survey some points on the ground with targets or with particularly visible landmarks.
It is also true that the reliability of GCPs is higher, thanks to the use of a specific sensor. It has happened, in fact, that flying in RTK the signal was lost, probably due to the high distance from the closest permanent network station (about 35 km).

Figure 7. Comparison between the photogrammetric point clouds respectively produced using a Sony A7III with 35 mm lens (1), a DJI Air 2s with flight plan (2), a DJI Mavic 3E with manual flight (3).

Also on a drone, but this time a *DJI Matrice 300*, the use of a multispectral camera (*Micasense Altum*) was tested to investigate the present plant species. In this case as well, the flight allowed the obtainment of a photogrammetric orthomosaic, supported by GCPs on the ground.
Finally, the last field of investigation was remote sensing. With the purpose of developing a more detailed analysis of the territory (e.g. evaluating the kinds of soil and vegetation or understanding possible risks for the heritage, like in Agapiou et al., 2020), a multispectral satellite image was acquired. This type of information will be later related to the higher-resolution observations acquired with the sensor mounted on the drone.
Therefore, it is evident how today's technology allows for a very extensive horizontal analysis, but also that multiple tools with different characteristics allow for obtaining data with similar features.

3.6 Features of the recorded information

It was mentioned that the primary objective of the survey was the acquisition of point clouds and orthophotos. An aspect of non-secondary relevance concerns the level of detail of the obtained data.
The survey was designed to balance acquisition timelines and final product resolution.
Generally, drone flights aimed to achieve a Ground Sampling Distance (GSD) between 2 and 5 cm, as this is the precision achievable in terms of GNSS georeferencing.
The images and point clouds were indeed incorporated into the RDN2008 UTM zone 32N reference system, followed by the calculation of the orthometric height of the coordinates. By doing so, it was possible to obtain accurate information not only in East and North but also in the vertical dimension.

4. MODELLING AND DATA ANALYSIS

To understand how to combine information at the BIM and GIS levels, particular attention was given to the infrastructure sector. Here, the need to combine this kind of data, along with the requirement to manage projects at very different scales, has already led to partial integration.
Specifically, the interest was mainly referred to Autodesk Infraworks, representing a tool with great potential in this regard. It not only allows for the creation, modification, and management of BIM objects within a GIS space but also facilitates the import of additional types of information, ranging from Autodesk Revit formats to ESRI Shapefiles, point clouds, Digital Elevation Models (DEMs), and raster images.
This application, therefore, was identified as the basic environment in which to develop the research.
However, as extensively shown, the need is to work at different scales and on various types of information, where obtaining an adequate level of detail is a fundamental requirement. For the modelling of architectural objects (from small structures like washhouses to complex buildings), the choice was made to use Autodesk Revit, a key software in this field. Similarly, for adequate accuracy in representing geographic information, software such as QGIS or ArcGIS still proves to be the most efficient solution.
In any case, as explained, all these formats are easily and directly importable, along with their management within the digital environment.
In doing so, some of the classic integration problems are easily overcome, such as geometric representation and the correspondence of geographic and local reference systems.
For now, the investigation has focused on modelling the current state of architectural structures only, intending to begin to contextualize what is provided by the *Model Builder* function of Infraworks, which will be described later. Anyway, a general schema of the modelling process is shown in Figure 8.
The aim, as highlighted in the initial paragraphs, will be to reconstruct all the characteristics of the territory for a comprehensive representation.

4.1 Set-up of the BIM-GIS model

First of all, the choice of the case study was directed towards a specific geographic reference system, identified with the *Rete Dinamica Nazionale 2008 – UTM zone 32N* (EPSG:7791).
With this preliminary step, a relevant issue was immediately addressed: the absence of this coordinate system in the Autodesk library. With the help of an additional application, Autodesk Civil 3D, it is possible to overcome the problem, obtaining what is necessary with little effort.
The next phase involved defining the intervention area. For contexts like the one under examination, reasoning within municipal limits may prove to be less meaningful, as there are often interrelations with neighbouring territories due to the exploitation of raw materials such as forests, pastures, mineral deposits, etc., or the presence of commercial and non-commercial communication routes.

Therefore, an extension that also includes part of the neighbouring municipalities was considered, allowing for the display of these reciprocities.
The Model Builder function allows for obtaining a preliminary set of data (derived from open-source databases) that defines the major characteristics of the landscape. It includes a simplified DEM (with low resolution), indicative representations of hydrographic and road networks (at different levels of detail), land uses, and building volumes.
Regarding communication systems, the highest level of detail is found among the types just listed, as Infraworks is precisely an application designed to intervene in this kind of infrastructure. However, it is almost always necessary to work on this type of data, which, being open, is also very generic.
As for building volumes, it was found that they rarely correspond to the real shape.
So, from this starting point, it was necessary to enrich the cartographic base with progressively more detailed information, meeting the representation needs.
This includes, for example, elevation models and vectors provided by the geoportal of the Lombardy Region, which already allow for a significant increase in scale.
However, for truly accurate data, it was necessary to use what was collected in the field, allowing for a highly precise representation of the real image of what was surveyed, both in terms of geometry and land use and in terms of the contour of the existing structures.

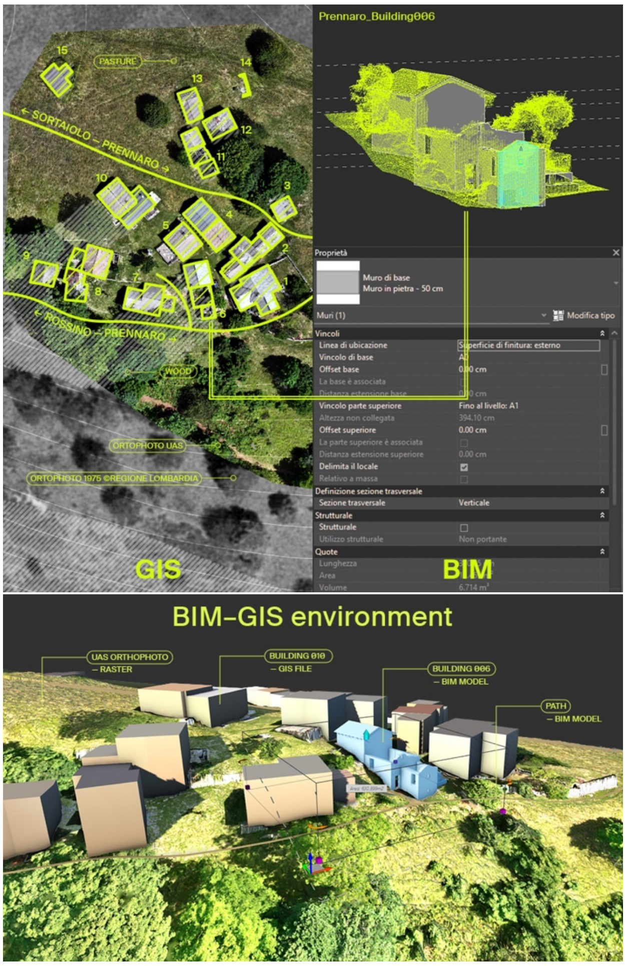

Figure 8. Example of the modelling phases on a single settlement. BIM and GIS data of different types, used for the representation and interpretation of the heritage, are integrated into a single Autodesk InfraWorks model.

4.2 Built environment modelling

So, with an appropriate cartographic base defined, the next step was to detail the characteristics of the built heritage, which has been used as a pivot from which to gradually extend to the landscape.
The process began with the cataloguing of structures within the various settlements. This assigned a unique code to each one, allowing for the construction of a catalogue of pre-existing structures.
From here, individual HBIM models were created for each architectural object in the territory, based, of course, on the acquired point clouds. This enables the creation of an organized and efficient archive, easily queried.
Following the initial survey, the available information only covers the external shape of structurally sound buildings and the internal shape of partially collapsed or inspectable ones.
For a comprehensive understanding of the built environment, this is a significant limitation that prevents the inventorying of all the specificities initially referred to.

5. CONCLUSIONS AND FUTURE STEPS

The research is just getting started, but it has already helped to frame a series of particularly relevant issues not only for the BIM-GIS integration theme for heritage, but also for the knowledge and project management of Italian Inner Areas.
The creation of this digital environment, thanks to both indirect research phases (bibliography, archives, databases, etc.) and direct ones (surveys and on-field observations), is enabling a deep understanding of the case study and an effective organization of information. However, there is still a need for substantial enrichment of information both horizontally and vertically.
Of particular interest is the future possibility of developing comprehensive analyses of the territory and structures, achievable once the modelling of all investigated settlements is completed.
The objective is to understand the practical usability of this digital tool not only in its effectiveness within the context of Inner Areas (systematising current and historical information for the development of new projects), but also and especially in the range of applications for the operators, who may not necessarily be specialists in the field.
At the moment, in fact, a doubt has already arisen: who the recipient of such an object could be. Will it be directed to a municipal technical functionary or to a specialist in these systems? Although the first hypothesis would be the most interesting to pursue, even in terms of a future application of the method, at the moment it does not seem to be the most feasible.
Anyway, the research will try to answer these questions and, if possible, identify the ways that will allow extensive use of this tool.

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