

Modern Tools and Methods for the Digital Investigation of Romanian Rural Cultural Landscapes: From Data Acquisition to Heritage BIM

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Abstract: The management of cultural landscapes in protected areas stands, today, at a methodological crossroads: traditional territorial and urban planning instruments (general urban plans, zonal urban plans, and zonal urban plans for protected built areas) often function as static regulatory devices, unable to capture the physical, spatial, and socio-cultural dynamics of historic sites, particularly those located in rural environments. This paper proposes an integrated methodological framework that links modern spatial data acquisition and analysis workflows to local planning and governance instruments. The core of this approach lies in the functional transition from standard Building Information Modelling (BIM) to Heritage Building Information Modelling (HBIM), adapted to the scale of the rural cultural landscape. Extending information modelling from the architectural object to the territorial context brings clear advantages for monitoring interventions and assessing environmental and heritage impact, while raising methodological challenges related to scalability, institutional interoperability, and the degree of subjectivity inherent in interpreting successive historical strata. The paper further examines, through a structured SWOT analysis, the strengths, weaknesses, opportunities, and threats associated with BIM/HBIM adoption in the Romanian rural context, arguing that the principal obstacle is institutional rather than technological. The paper concludes with applied recommendations for a graduated, priority-based strategy of digitalization, oriented toward the active protection and integrated conservation of protected cultural landscapes.

Keywords: Rural Cultural Landscape, BIM, Heritage BIM, Urban Planning Documentation, Digital Data Acquisition, Sustainable Urbanism, Protected Areas, Romania

1. Introduction

The author's ongoing doctoral research, entitled "The Rural Cultural Landscape: From Identity to Sustainability. Modern Tools and Methods for Investigating, Protecting and Valorising Rural Landscapes in the Sustainable Planning Process," established, during its theoretical stage, the major conceptual reference points of the field: the categories of cultural landscape established by UNESCO (UNESCO World Heritage Centre [WHC], 2008), the notion of territorial capital, which includes natural and built resources as well as relational and symbolic ones (Camagni, 2009), and the principle of sustainable development articulated around the balance of the three pillars - economic, social, and environmental (World Commission on Environment and Development [WCED], 1987). The central premise of this framework is that the rural cultural landscape exceeds the status of mere décor, constituting the material support of the collective identity of communities (Council of Europe [CoE], 2000; Stobbelaar & Pedroli, 2011).

Building on these foundations, this paper proposes a less-explored direction: the operationalization of integrated rural cultural landscape management through modern analysis and planning tools. The argument moves from an examination of territorially available investigation technologies to the concrete instrument through which they can be translated into design, permitting, and monitoring practice, namely Building Information Modelling (BIM) and its heritage-dedicated extension, Heritage BIM (HBIM). The stake of the paper lies in identifying the methodological and technical means applicable throughout the planning process: from the acquisition of data on the history and current state of the territory, to the analysis and correlation of foundation studies with the regulations established through urban planning documentation - the General Urban Plan (PUG), the Zonal Urban Plan (PUZ), the

Zonal Urban Plan for protected built areas (PUZCP) - and with the requirements of the various approving authorities involved.

The paper follows two main directions. Section 2 identifies the modern tools and methods for territorial investigation, from the acquisition of historical and current data, to their correlation with urban planning documentation and approving-authority requirements. Section 3 examines the impact and benefits of using BIM-type information models on human communities, through a SWOT analysis dedicated to the Romanian rural context. The paper concludes with a summary section. A second, complementary paper separately addresses regulation, the monitoring of interventions in protected areas, and participatory data governance.

Methodologically, the paper combines an analysis of the international literature on BIM, HBIM, and related tools with a detailed analysis of the Romanian legal framework governing urban planning documentation and the approval procedure - a regulatory layer essential for understanding how the technological tools discussed can be effectively integrated into Romanian planning practice.

2. Modern Tools and Methods for Territorial Investigation

Identifying modern tools for territorial investigation constitutes the first, mandatory step of any sustainable planning process. Figure 1 summarises the integrated workflow proposed by this paper, from data acquisition to intervention-implementation monitoring - a flow that also organizes the structure of this section.

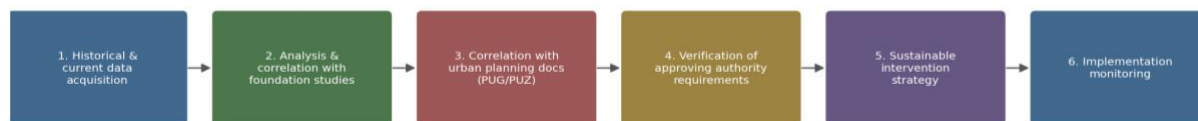


Figure 1. Integrated workflow from territorial investigation to intervention monitoring

Source: Author's elaboration, based on the literature and legislation cited in the text

2.1. Instruments for Acquiring Historical and Current Data

The acquisition of data on a territory's history primarily involves consulting cadastral archives, historical maps - from the eighteenth-century Austrian surveys to interwar or socialist-era parcel plans - and archival aerial photographs, where available. These historical sources acquire, in this paper, an instrumental dimension: they constitute the raw material for any subsequent digital model of the territory, regardless of its degree of technical sophistication. Data on the current state of the territory is obtained today through a combination of instruments: orthophotoplans and digital terrain models generated through unmanned aerial vehicle (UAV) photogrammetry, LiDAR data for areas with dense vegetation cover, and periodically updated GIS databases. The novel element specific to this paper lies in transforming this raw data - points, orthophotoplans, digital terrain models - into structured information models capable of directly supporting the permitting and authorization process described in the following subsections.

An important methodological distinction concerns the difference between simply archiving historical data digitally and actively integrating it into a queryable model. Scanning a historical map and saving it as a digital image is, of course, a useful conservation step, but does not, by itself, produce a useful planning tool, as long as the image remains non-editable and non-georeferenced. Georeferencing historical maps - the process of associating common control points between the old map and the current coordinate system - transforms these archival documents into active layers of a GIS model, directly comparable with the current state of the territory. This operation, relatively simple technically but time-consuming,

remains, in the author's view, one of the most underused methodological resources available for documenting the rural cultural landscape.

2.2. Instruments for Analysis and Correlation with Foundation Studies

Foundation studies - geotechnical, topographic, hydrogeological, traffic-related, historical - constitute the mandatory technical basis of any urban planning documentation. Correlating these studies, often prepared by different specialists, at different times, and with different methodologies, remains, in current practice, a predominantly manual process, based on the visual overlay of drawn plates. GIS tools allow for much more rigorous correlation, through the common georeferencing of all foundation studies within a single coordinate system, which facilitates the automatic identification of overlaps, contradictions, or information gaps between the different studies. BIM models, and especially their GeoBIM-type extensions, offer a further step beyond simple GIS overlay: the possibility of integrating foundation studies directly into the three-dimensional model of the territory, with all their associated semantic attributes (Noardo et al., 2020). A geotechnical study identifying a zone with reduced soil bearing capacity no longer remains isolated information on a separate plate, but becomes a queryable attribute of the digital model of that zone, visible simultaneously with urban planning regulations and any heritage constraints.

The practical challenge of this integration nevertheless remains considerable. In current Romanian practice, foundation studies are prepared by different specialized offices, often without an explicit requirement to deliver data in a structured digital format compatible with the beneficiary's GIS or BIM models. Introducing, at the level of technical specifications, an explicit requirement for delivery in structured digital format - georeferenced, with editable attributes - could significantly reduce this conversion cost, facilitating the subsequent integration of studies into the workflow described in Figure 1.

2.3. Urban Planning Documentation: PUG, PUZ, PUD, and PUZCP

The Romanian legal framework structures urban planning documentation across several levels of detail, each with a specific role and content. The General Urban Plan (PUG), accompanied by the Local Urban Planning Regulation (RLU), regulates the entire administrative territory of a locality. The Zonal Urban Plan (PUZ) details the PUG regulations for a zone characterized by a high level of complexity. The Detailed Urban Plan (PUD) regulates an individual parcel (National Institute of Administration [INA], n.d.). A specific type of documentation is the Zonal Urban Plan for protected built areas (PUZCP), regulated through Order of the Ministry of Transport, Construction, and Tourism no. 562/2003. The general legal framework for the preparation, approval, and endorsement of all these documentation types is established by Law no. 350/2001 and the methodological norms for its application, approved through Order MDRAP no. 233/2016. The General Urban Planning Regulation, approved through Government Decision no. 525/1996, complements this framework with generally applicable technical provisions.

Table 1. Comparison of the Four Categories of Urban-Planning Documentation

Documentation	Regulatory scale	Specific legal basis	Relevance for rural heritage
PUG + RLU	Entire administrative territory	Order MDRAP no. 233/2016	General zoning, including delimitation of heritage-value areas
PUZ + RLU	Zone of high complexity	Order MDRAP no. 233/2016	Detailed regulations for a specific rural zone
PUD	Individual parcel	Order MDRAP no. 233/2016	Detailing the siting of an individual construction
PUZCP	Protected built area	Order MTCT no. 562/2003	Explicit inventory and assessment of heritage value

Note. Synthetic comparison between the main categories of urban planning documentation regulated by Law no. 350/2001. *Source:* Author's elaboration.

For small rural local administrative units (LAUs), preparing and updating this documentation often remains a slow and costly process, aggravated by limited administrative capacity. Integrating the digital tools discussed in this paper into the process of preparing urban planning documentation is therefore not merely a marginal technical improvement, but a possible solution to a real structural problem.

2.4. Approving Authority Requirements in the Authorization Process

Obtaining a building permit requires, under Law no. 50/1991 on the authorization of construction works and its methodological norms, going through an approval process involving a multitude of institutions, whose specific requirements are established through the urban planning certificate. Figure 2 illustrates, in simplified form, the main approving authorities involved in this process for a typical rural-territory intervention project.

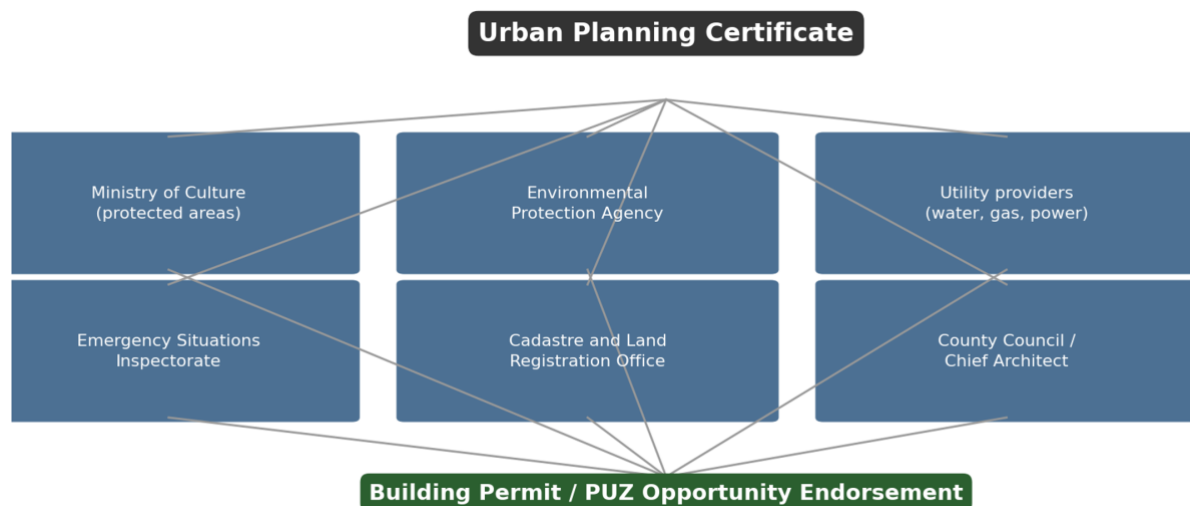


Figure 2. Examples of Authorities Involved in the Approval Process for Rural-Area Interventions
Source: Author's elaboration, based on Law no. 50/1991

For interventions in protected areas, the Ministry of Culture's endorsement becomes mandatory, along with approvals from the Environmental Protection Agency and utility providers. In practice, the average time to obtain these approvals varies between 30 and 60 days, and the absence of any required approval blocks issuance of the building permit. At international level, a similar principle of prior approval governs interventions on sites inscribed on the UNESCO World Heritage List (ICOMOS, n.d.).

The cumulative effect of these successive approval periods - each of 30-60 days, often carried out sequentially rather than in parallel - can extend the total duration of the authorization process for a project located in a protected area to six months or more. For individual owners of rural properties with heritage value, such an extended duration can discourage a restoration effort from its incipient phase. The multiplication of approving authorities constitutes a further argument for the usefulness of a single BIM- or GeoBIM-type information model, capable of generating, from a single structured database, the specific documentation requested by each approving authority.

2.5. The Single Digital Window - A Direction for Procedural Reform

The multiplication of approving authorities discussed in Section 2.4 has generated, at European level, an increasingly adopted direction of procedural reform: the single digital window, through which an applicant for authorization interacts with a single IT platform, which is itself responsible for internally routing the request to all relevant approving institutions. Although Romania has made limited progress in this direction, a complete single digital window, capable of

automatically integrating all the approvals discussed in Figure 2, remains, for most rural LAUs, a distant objective.

The instruments discussed in this paper - structured BIM/HBIM models, compatible with the ISO 19650 standard (International Organization for Standardization [ISO], 2018) - could theoretically constitute the technical foundation of such a single window. The practical implementation of such a system requires, however, a major institutional investment, beyond the resources of any individual LAU, which is why such a reform should realistically be conceived at national or regional level.

3. The Impact and Benefits of Using Building Information Models (BIM) on Human Communities

This section examines in depth the impact dimension on human communities, focusing on the applicability of BIM for rural heritage and on a structured SWOT analysis of the opportunities and risks that its adoption entails in a rural context. Internationally, information management standardization in BIM projects is governed by the ISO 19650 standard, which establishes unified principles for organizing, sharing, and managing data throughout the entire life cycle of a built asset (ISO, 2018). The standard introduces the concept of the "Common Data Environment," a centralized platform through which all actors involved in a project access a single, updated version of the information about the construction in question.

3.1. From BIM to Heritage BIM (HBIM): Applications for Rural Heritage

While classic BIM is primarily oriented toward the design and execution of new construction, a specialized branch - Heritage Building Information Modelling (HBIM) - has developed specifically for the documentation, conservation, and management of existing buildings with heritage value. The term was introduced in 2009 by Murphy, McGovern, and Pavia, to describe how BIM-specific workflows can be adapted to historic structures (Murphy et al., 2009). Figure 3 synthetically illustrates the main distinctions between classic BIM and HBIM.

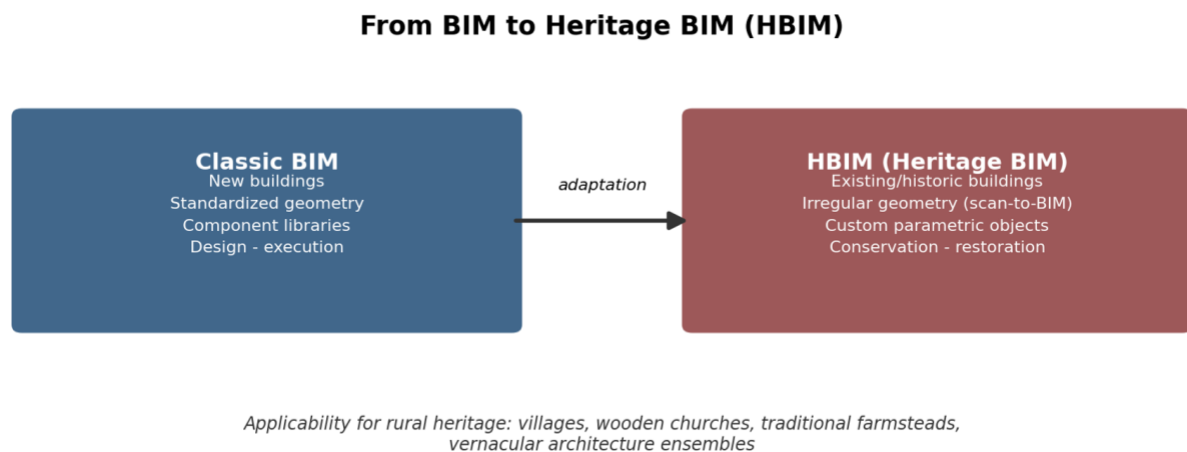


Figure 3. Main distinctions between classic BIM and Heritage BIM (HBIM)

Source: Author's adaptation based on Murphy et al. (2009) and subsequent literature

Unlike classic BIM, which operates with standardized geometries and predefined component libraries, HBIM begins with a reality-capture stage - laser scanning (terrestrial LiDAR) or photogrammetry - whose data is subsequently converted into custom parametric models, capable of capturing the geometric irregularities specific to old buildings (Bastem & Cekmis, 2022). This process, known in the specialized literature as "scan-to-BIM," is recognized as one of the most efficient strategies for the initial development stage of an HBIM model (Martín-Lerones et al., 2021). Specific methodologies, developed to represent the constructive systems of built heritage,

propose HBIM workflows adapted to this additional complexity (Martinelli et al., 2022), while early studies, such as the one dedicated to an object library for historic buildings in Jeddah, demonstrated the feasibility of the approach from the early years of HBIM adoption (Baik et al., 2014).

The applicability of HBIM to rural heritage is direct: villages with ensemble value, wooden churches, traditional farmsteads, or vernacular architecture ensembles can benefit from the same methodology initially developed for individual urban monuments (Osello et al., 2018; Jordan-Palomar et al., 2018). For properties listed under Law no. 422/2001 on the protection of historical monuments, a complete HBIM model could complement the documentation obligations already imposed on owners through the historical-monument regime, offering authorities a more solid technical basis for approving subsequent interventions. Nevertheless, the specialized literature also identifies significant limitations of HBIM: the absence of standardised methodologies remains a persistent difficulty for implementation, and some earlier attempts to adapt classic BIM procedures to HBIM have been considered unsuccessful, precisely because BIM was originally conceived for new construction, not for the complexity of historic structures.

3.2. Beneficiaries and Impact on Human Communities

The direct beneficiaries of BIM and HBIM models applied to rural territory are multiple. Local public authorities benefit from a structured database, which can directly support the approval process and reduce urban planning documentation processing times. Owners of heritage-value properties benefit from precise documentation of the existing state of their buildings, useful both for substantiating any restoration interventions and for accessing funding schemes. Researchers and cultural institutions, in turn, benefit from a permanent digital resource, usable for research, education, and public dissemination.

The broader community impact, however, goes beyond the technical sphere of documentation. International heritage-digitisation projects have demonstrated that the scanning and modelling process can itself become a vehicle for community involvement, particularly when residents are invited to contribute historical information, family photographs, or oral accounts that complement the purely geometric data of the digital model. This participatory dimension transforms HBIM from a mere technical instrument into a possible catalyst for community regeneration.

3.3. SWOT Analysis of BIM Use in the Rural Context

SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) is one of the most widespread strategic planning tools, with origins in corporate planning research conducted at the Stanford Research Institute in the 1960s, under the coordination of Albert Humphrey (Puyt et al., 2023). Applied to BIM use in the Romanian rural context, SWOT analysis offers a useful tool for synthesizing the internal and external factors relevant to the technology-adoption decision. Figure 4 proposes such an analysis.

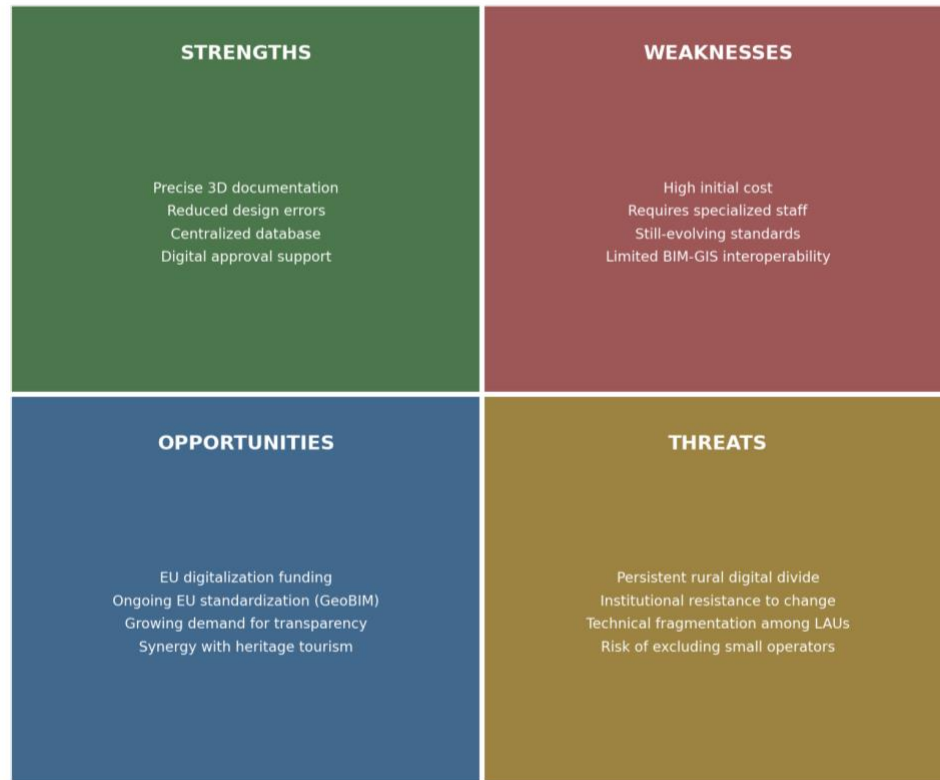


Figure 4. SWOT analysis of BIM use in the Romanian rural context
 Source: Author's elaboration, based on the literature on BIM adoption

The strengths identified in Figure 4 are consistently supported by the international literature: a systematic synthesis of BIM benefits in infrastructure projects confirms improved collaboration, real-time data-driven decisions, and significant cost and time reductions (Alsofiani, 2024). A cost-benefit study applied to public projects in the Czech Republic estimates the cost of BIM implementation at approximately 0.4% of investment value, with projected savings of up to 1.68% of total investment for infrastructure projects (Věrný & Žák, 2025). Across the entire non-residential construction sector, full process digitalization is estimated to generate annual savings of 13-21% in the design and construction phases and 10-17% in the operation phase, according to the European Construction Sector Observatory (BIMobject, 2022). Figure 5 summarises these estimates.

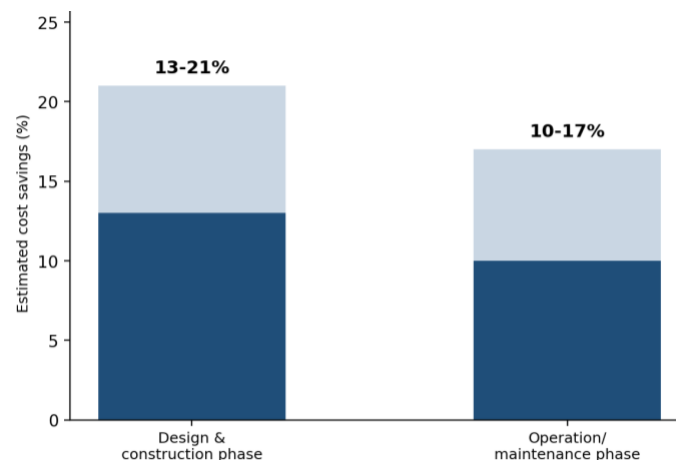


Figure 5. Estimated cost savings from full digitalization (BIM) of non-residential construction projects
 Source: European Construction Sector Observatory, cited in BIMobject (2022)

The weaknesses and threats identified in the SWOT analysis are, however, no less relevant. A systematic review of barriers to BIM adoption identified 74 distinct barriers, grouped into seven main categories: education and training difficulties, resistance to change, lack of clearly perceived business value, perceived excessive costs, absence of standards and guidelines, absence of legal adoption mandates, and absence of institutional support initiatives (Alsofiani, 2024). Many of these barriers directly overlap with the obstacles of a rural context: limited administrative capacity, digital divide, high costs.

A final observation on the SWOT analysis concerns the interaction between its four quadrants. The strengths and opportunities identified in the upper part of Figure 4 - precise documentation, available EU funding - cannot automatically translate into concrete results without explicitly addressing the weaknesses and threats in the lower part. For instance, the availability of EU digitalization funds, identified as an opportunity, remains unusable for an LAU lacking the specialized staff needed to draft a competitive funding application - precisely the weakness identified in the opposite quadrant. This interdependence suggests that the optimal strategy for a rural LAU does not lie in the isolated maximisation of strengths, but in identifying interventions capable of simultaneously mitigating a weakness and leveraging a related opportunity. The synthesis of the SWOT analysis suggests a nuanced conclusion: the economic and technical potential of BIM for supporting sustainable rural urbanisation is real and well documented in the international literature, but its effective realisation, in the specific context of Romanian rural LAUs, remains conditioned on overcoming the institutional and financial barriers already identified. The principal gap is not purely technological, but one of governance and institutional capacity.

4. Conclusions

This paper has sought to identify and systematize the modern tools for the digital investigation of the Romanian rural cultural landscape, from the acquisition of historical and current data to BIM and HBIM models. Three main conclusions emerge from the analysis. First, the technical instruments discussed are mature and well documented in the international literature, but their effective integration into the Romanian approval and authorization process, structured around urban planning documentation and a multitude of approving authorities, remains, for now, incomplete. Second, the SWOT analysis confirms that the technological and economic benefits of digitalization are real, but their effective realization is conditioned on institutional factors - administrative capacity, governance, financial resources - rather than on the technical availability of the instruments themselves. Third, the gradual adoption of BIM/HBIM, through limited-scope pilot projects, appears a more realistic strategy than an exhaustive digitalization initiative, difficult to implement uniformly across all rural local administrative units.

A second, complementary paper separately addresses how these tools can substantiate a sustainable intervention strategy, the ways of monitoring interventions in protected areas, and the role of participatory data governance in ensuring the long-term sustainability of this methodological framework.

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