

Special Issue on Heritage Buildings: Latest Advances and Prospects

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1. Introduction

Heritage buildings are not static survivors of the past. They are long-lived material systems in which construction techniques, repairs, environmental exposure, and changes in use and cultural meanings accumulate over time. Their conservation therefore depends on the capacity to read this stratification and to translate it into informed choices. The central challenge is no longer arresting decay: it is to preserve significance while taking safety, use, adaptation, and environmental responsibility into account, and without reducing heritage buildings to conventional building stock.

This challenge has altered both the scale and the instruments of research. Historical analysis, material characterisation, non-destructive testing, structural modelling, digital survey, geographic information systems, energy simulation, and information modelling are increasingly combined rather than applied as isolated procedures. At the same time, sustainability is being reformulated in heritage-specific terms. This concerns not only energy demand, but also the compatibility and durability of interventions, the retention of embodied cultural and material value, the reversibility of change, the continuity of local knowledge, and the capacity to manage resources over extended life cycles.

The Special Issue “Heritage Buildings: Latest Advances and Prospects” brings together nine contributions that examine these questions, looking at different building types, territorial contexts, and methodological scales. Their novelty lies less in the use of individual tools than in the way they connect evidence, interpretation, and decision-making. Taken together, the papers address four closely related trajectories: the construction of integrated knowledge from heterogeneous sources; the extension of conservation towards risk, resilience, and territorial assessment; the reformulation of sustainability through design, materials, and supply chains; and the transition from digital documentation to material traceability and decision support. The following sections discuss the specific contribution of each paper while drawing out the broader advances that emerge from this Special Issue as a whole.



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2. Latest Advances in Heritage Building Research

A first line of advance concerns the transformation of documentation into an interpretative infrastructure for conservation. In the study of the Church of Santos Juanes in Valencia, historical research, three-dimensional laser scanning, infrared thermography, ground-penetrating radar, and finite element modelling are integrated to reconstruct the building’s constructional configuration and assess its response under static and seismic actions [1]. The significance of the work lies in the combination of evidence that is usually

examined separately. Geometric irregularities, concealed elements, subsoil conditions, and crack patterns are brought into a single analytical framework, allowing for structural interpretations to be tested against the material reality of the monument.

The study of Gordon Matta-Clark's architectural cuts addresses the opposite condition: heritage for which direct survey is incomplete, unsafe, or no longer possible [2]. Through exploded axonometries, orthographic projections, and analytical diagrams, geometric reconstruction is used to organise fragmentary visual evidence and to prepare an initial HBIM-oriented knowledge base. This contribution is particularly relevant because it reframes drawing as a method of inference. Digital documentation is not treated as the mechanical capture of an existing object, but as a critical process for recovering spatial relationships from incomplete records.

A second line of research expands conservation from the treatment of damage to the anticipation of risk. The fire-resilience assessment of a historic university building in China proposes an IDIA model combining the improved Delphi method, Interpretive Structural Modelling, and the Analytic Network Process [3]. Rather than reducing fire safety to compliance with technical prescriptions, the study identifies the interdependence of construction characteristics, protection systems, organisational preparedness, and user behaviour. This systemic reading is especially important in historic educational buildings, where continued occupation, dense use, obsolete installations, and constraints on alteration can create forms of vulnerability that prescriptive approaches do not adequately capture.

The GIS-based assessment of the fortified heritage of Castellón extends this systemic perspective from the building to the surrounding territory [4]. Documentary analysis, field survey, and spatial indicators are combined to evaluate authenticity, integrity, and scenic value across a network of approximately 150 fortifications. One of the most consequential findings is that physical completeness and heritage sustainability do not necessarily coincide: many rural castles remain in ruins while retaining strong visual integrity and meaningful relationships with their landscape. The study therefore challenges restoration-centred metrics and shows that conservation decisions must also account for topography, viewsheds, settlement patterns, and cultural continuity.

Sustainability is addressed in this Special Issue not as a single performance target but as a set of design and management choices conditioned by heritage value. The study of the Antonio Rueda housing complex applies a BIM-based workflow to compare nine retrofit scenarios, from reversible envelope improvements to volumetric extensions, while assessing operational carbon and indoor lighting [5]. Its contribution lies in replacing the idea of a universal retrofit solution with a scenario-based evaluation in which environmental gains are weighed against architectural identity, constructive logic, and the degree of transformation introduced.

The intervention at the Church of San Juan del Hospital explores sustainability through the design of a contemporary addition [6]. The project resolves access, enclosure, circulation, and environmental control requirements through materials and construction systems selected for durability, compatibility, reversibility, and reduced environmental impact. The use of aluminium, recycled wood, and handmade ceramic brick avoids imitation while establishing a controlled relationship with the medieval fabric. The paper demonstrates that sustainability in heritage architecture is inseparable from design judgement: technical adequacy must be matched by formal clarity, the legibility of the new intervention, and respect for the historical structure.

The research on the sheep's-wool supply chain broadens the discussion from buildings to the productive ecosystems that make sustainable materials available [7]. Mapping more than 200 actors, the study identifies the potential of wool as a local, bio-based resource for construction and built heritage, but also exposes the regulatory and organisational

obstacles that limit its use. The very small proportion of farms that formally recognise wool production as a business objective, together with waste-classification constraints and fragmented processing capacity, show that material innovation cannot be separated from supply-chain governance. The paper thus links heritage conservation to territorial economies, cross-sectoral knowledge, and the recovery of underused regional resources.

The final two contributions address a decisive shift from digital recording to the structured management of material information. The study of Material and Product Passports examines how passport systems developed for contemporary construction can be adapted to heritage buildings [8]. Its main contribution is to show that a heritage-oriented passport cannot be reduced to a catalogue of product properties. It must connect technical data with historical transformations, conservation events, cultural significance, authenticity, reversibility, and contextual sensitivity across maintenance, rehabilitation, and adaptive reuse processes.

Building on this premise, the Building Heritage Material Passport-based framework introduces a multi-criteria system that directly links documentation to intervention choices [9]. Compatibility and durability are combined with traceability and cultural value through fuzzy scoring, context-sensitive weighting, and the Analytic Hierarchy Process. A threshold-based mechanism then translates the assessment into conservation or reuse strategies. The methodological advance lies in making explicit the criteria through which material knowledge becomes operational: the passport is no longer a passive repository, but a transparent decision-support environment for degraded, partially collapsed, or adaptively reused heritage buildings.

Across these nine papers, the most important common development is the integration of domains that often remain separate. Surveys are connected with diagnoses; diagnoses with simulations; risk assessments with organisational behaviour; landscape analyses with material conditions; retrofitting with architectural judgements; bio-based materials with territorial supply chains; and digital records with decision rules. The resulting picture is not one of technological replacement, but of a more mature conservation practice in which different forms of evidence are coordinated according to the specificity of the heritage asset.

3. Future Prospects

The contributions also reveal several priorities for future research. The first is interoperability. Heritage investigations produce point clouds, thermographic images, radar profiles, numerical models, GIS layers, energy data, archival records, and material histories, yet these sources are commonly stored in disconnected environments. Progress will require data structures capable of preserving provenance, uncertainty, temporal change, and interpretative status while enabling information to circulate between HBIM, GIS, digital twins, monitoring platforms, and material-passport systems.

A second priority is the transition from episodic diagnosis to adaptive management. The fire-resilience model, the integrated structural study, and the multi-criteria material framework all indicate the need for systems that can be revised as buildings change. Monitoring results, maintenance actions, new investigations, and transformations in use should update the knowledge base rather than remain detached reports. The challenge is not merely technical: decision-support systems must remain transparent, auditable, and intelligible when quantitative performance indicators are combined with qualitative cultural values.

A third field concerns the development of heritage-specific sustainability metrics. The criteria derived from new constructions cannot be transferred uncritically to historic buildings, because conservation itself extends service life, retains embodied energy and workmanship, and avoids the cultural and environmental costs of replacement. Future work should there-

fore compare operational benefits with the effects of intervention on authenticity, material compatibility, spatial character, maintenance demand, and reversibility. Life-cycle assessment, circularity indicators, and carbon accounting will be meaningful only when they recognise the extended time horizons and non-substitutable values of heritage materials.

Finally, the territorial and social dimensions of conservation require stronger integration into technical research. The studies on fortified landscapes and wool supply chains show that the viability of heritage depends on relationships that exceed the physical boundary of the building: landscape continuity, regional production, specialised skills, institutional coordination, community use, and local economies. The next generation of heritage research should therefore connect building-scale innovation with territorial governance and with the distributed knowledge of professionals, craftspeople, public authorities, and communities.

4. Conclusions

The papers published in this Special Issue provide a coherent account of how heritage-building research is evolving. They do not converge on a single technology or universal method. Instead, they demonstrate the value of combining historical interpretation, non-destructive investigation, structural and environmental modelling, risk assessment, design experimentation, material innovation, territorial analysis, and digital decision support according to the specific conditions of each asset.

The broader lesson is that conservation quality depends on the architecture of knowledge as much as on the sophistication of individual tools. Data become useful only when their origin, uncertainty, and cultural meaning are understood; sustainable solutions become credible only when environmental performance is reconciled with compatibility and significance; and circular strategies become applicable only when material information can guide explicit choices. The future of the field therefore lies in integrated and updatable knowledge systems that support preventive care, responsible adaptation, and long-term stewardship while preserving the material and cultural distinctions that make heritage irreplaceable.

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