AG Publishing House

Architectural Paradigms: Academic Research in Pedagogy, Heritage, and Sustainability

Year: 2026

Built Heritage Documentation techniques: Methods, Applications and Case studies

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Abstract

Documentation of built heritage is an integral part of the conservation process and is essential to providing accurate information to guide-built heritage preservation, restoration and long-term management. This review covers the development of the documentation process from the traditional surveying methods to the more recent ones such as measured drawings, total station surveys, the use of photogrammetry, terrestrial laser scanning (TLS/LiDAR), unmanned aerial vehicle (UAV) survey and Heritage Building Information Modelling (HBIM). The paper explores the key applications of these techniques for conservation planning, structural assessment, restoration, digital archiving, disaster risk management, tourism, deterioration monitoring and maintenance planning. It also identifies opportunities for development as well as significant challenges, such as high equipment costs, challenges with data processing, interoperability, lack of technical skills, lack of standardisation, and legal and ethical issues. Finally, the review highlights recent developments including the use of Artificial Intelligence, Digital Twin, cloud-based heritage management, and integrated HBIM-GIS platforms that are revolutionising the process of heritage documentation as a more intelligent, collaborative and sustainable heritage conservation.

[*] ISBN No. - 978-93-7640-203-8

Keywords: Built Heritage Documentation; Photogrammetry; Terrestrial Laser Scanning (TLS); Heritage Building Information Modelling (HBIM); Heritage Conservation.

1 INTRODUCTION

Built heritage such as historic buildings, monuments, archaeological sites and cultural landscapes are the cultural identity, architectural knowledge and historical evolution of societies. The conservation of these heritage assets is necessary to maintain the cultural continuity and to ensure sustainable tourism, education, research and the development of the social values, material heritage and traditional construction techniques. The threat of deterioration has been enhanced, however, by the tendency for a growing population, environmental degradation, climate change, natural disasters and material ageing, which has necessitated a systematic conservation and management of heritage resources [1].

Documentation plays a crucial role in the heritage conservation process as it provides reliable information regarding the geometry, materials, condition and historic significance of a structure prior to any restoration or maintenance work being carried out. Proper documentation enables condition assessment, restoration planning, structural monitoring and long-term management, and leaves a permanent record for future research and disaster reconstruction. Historically, heritage documentation was based on hand-measured drawings, photographs, and descriptions. These methods are still useful, but are time consuming and labour intensive, and can be less effective in capturing intricate architectural details [2], [3].

Heritage documentation has recently undergone dramatic changes because of the development of digital technologies. Digital photogrammetry, terrestrial laser scanning (TLS), Light Detection and Ranging (LiDAR), unmanned aerial vehicle (UAV) surveys and Heritage Building Information Modelling (HBIM) can be used to capture highly accurate three-dimensional data and integrated digital records quickly. These technologies enhance the efficiency, accuracy and accessibility of the documentation of heritage and facilitate multi-disciplinary heritage conservation planning and digital archiving [4], [5]. This shift from traditional surveying practices to digital records has thus emerged as a significant development in heritage conservation. This review focuses on the main documentation methods, their applications for conservation and selected case studies that illustrate their contribution to the conservation of built heritage.

2 BUILT HERITAGE DOCUMENTATION TECHNIQUES

There are two main categories of built heritage documentation methods: traditional and digital. The main techniques used to create architectural drawings are manual measurement and surveying instruments, while digital techniques use high-tech sensors and computer-based

processing to generate highly accurate two dimensional and three-dimensional images of heritage structures. Documentation can be done using a variety of techniques, which will depend on the scale and complexity of the monument, the level of accuracy needed, the resources available, and the conservation goals. Digital techniques have been used to enhance and not supplant traditional surveying methods, and have added detailed and efficient documentation to conservation work over the last few years [6].

1. **Measured Drawings and Total Station Surveys:** Measured drawings are one of the first ways of documenting heritage, traditionally hand-measured drawings of plans, elevations and sections. The use of total stations lent a new dimension to the process by facilitating accurate electronic measurement of distances and angles, resulting in accurate coordinate data for architectural surveys. While these methods tend to be more affordable and appropriate for smaller to medium sized heritage buildings, they do need a significant amount of time in the field and cannot efficiently collect detailed architectural information or irregular geometries [7].
2. **Photogrammetry:** The image-based algorithms that are used to reconstruct the 3D models of the image with photogrammetry are called algorithms. It is a non-contact solution that can capture complex architectural details with high visual quality at a lower cost. This technique is especially useful for the treatment of façades, sculptures, and archaeological remains, however, the accuracy relies upon the quality of the picture, lighting conditions, and camera calibration [8].
3. **Terrestrial Laser Scanning (TLS/LiDAR):** Terrestrial Laser Scanning (TLS) is also known as ground-based LiDAR, produces millions of spatial points within a brief time frame, and results in dense and accurate point cloud. This technique yields millimetre precision and is extensively used when it comes to documentation of complex monuments, deformation analysis, and structural assessment. Although TLS incorporates relatively high precision, it demands special equipment, specially trained staff and large data processing capacity, which makes it relatively expensive in terms of operation [9].
4. **UAV (Drone)-Based Documentation:** High resolution camera systems mounted on Unmanned Aerial Vehicles (UAVs) have proven to be a valuable tool to document roofs, towers, large archaeological sites and inaccessible areas. UAV surveys can be used to gather data quickly and create detailed orthophotos and 3D models of surfaces when combined with photogrammetry. However, they may not be suitable for use in certain heritage sites due to regulatory, weather and battery limitations [10].
5. **Heritage Building Information Modelling (HBIM):** Heritage Building Information Modelling (HBIM) is a tool that combines the geometric documentation with historical,

material and conservation data in a virtual environment. HBIM develops intelligent 3D models based on data collected through photogrammetry and laser scanning, to serve restoration planning, maintenance and the lifecycle management of a building. While HBIM provides all information management and multidisciplinary collaboration, it will demand a lot of data preparation, specialized software, and experts [11].

Digital documentation techniques offer enhanced accuracy, efficiency, and data integration compared to traditional methods, while traditional documentation remains useful for basic architectural documentation. Compared with other survey techniques, photogrammetry and UAV surveys are relatively low in cost, TLS is the most accurate in terms of geometry and HBIM is the most comprehensive platform for long-term heritage management, combining spatial and semantic data.

3 APPLICATIONS OF HERITAGE DOCUMENTATION IN CONSERVATION

Documentation of built heritage is not just about describing the physical features of historic buildings and structures, it also records the information required to plan, conserve, manage and preserve built heritage for future generations. The use of modern documentation techniques provides trustworthy and accurate geometric and semantic data to facilitate informed decision making in the heritage conservation process. Documentation has now become an essential tool for sustainable management of heritage, combining digital models (and representations) with historical and structural data [12].

- **Conservation Planning:** Conservational planning can be based on accurate documentation, which documents the geometry, materials, historical features and current condition of heritage assets to provide a reliable baseline. These records can help conservation professionals prioritize interventions, inform conservation strategy, and develop scientifically sound conservation strategies while minimising unnecessary changes [13].
- **Structural Condition Assessment:** Terrestrial laser scanning (TLS), photogrammetry and aerial surveys using unmanned aerial vehicles (UAVs) are documentation technologies that allow for detailed structural assessments, including identifying cracks, deformation, displacement, and material deterioration. Three dimensional data allow engineers to make comparisons between sequential surveys, and assess the stability of the structure, without doing physical damage to the monument [8].
- **Restoration and Rehabilitation:** Digital documentation can be valuable in restoration by capturing detailed measurements and records of building features prior to work being done. Three dimensional models enable conservators to recreate damaged features,

replicate decorative details and check the accuracy of restoration interventions, while ensuring their interventions are consistent with the original architectural character [14].

- **Digital Archiving:** Digital documentation enables the creation of permanent archives with geometric data, photos, historical records and maintenance data. The digital repositories will not only hold valuable heritage information for future research, conservation planning, education and public access, but will also be able to cope with deterioration or partial loss of the original structure [15].
- **Disaster Risk Management:** Good and precise digital records are critical to disaster preparedness and disaster recovery. The documentation allows a quick damage evaluation after earthquakes, floods, fires, or conflicts and serves as a reference for rebuilding. Digital inventories also assist in the risk mapping and emergency preparedness plans for vulnerable heritage sites [16].
- **Tourism and Virtual Heritage:** Creating virtual tours, interactive visualisations, augmented reality (AR) and virtual reality (VR) experiences to boost the public understanding of cultural heritage benefits from being documented in three dimensions. These applications represent an approach that enhances access to the remote audiences and is also contributing to heritage education and sustainable cultural tourism without adding pressure on the physical structure of fragile monuments [17].

Table 2: Applications of Built Heritage Documentation in Conservation

Application	Purpose	Documentation Techniques Commonly Used	Key Benefits
Conservation Planning	To establish baseline information for developing conservation and management strategies.	Measured drawings, Total Station Survey, Photogrammetry, TLS/LiDAR, HBIM	Provides accurate geometric and historical records; supports informed decision-making and prioritisation of conservation interventions.
Structural Condition Assessment	To evaluate the physical and structural condition of heritage buildings.	TLS/LiDAR, Photogrammetry, UAV Survey, Total Station	Detects cracks, deformation, settlement, displacement, and structural defects with high accuracy and enables non-destructive inspection.
Restoration and Rehabilitation	To support repair, reconstruction, and rehabilitation of damaged heritage structures.	TLS/LiDAR, Photogrammetry, HBIM	Produces precise measurements for restoring architectural elements while preserving authenticity and historical integrity.

Digital Archiving	To preserve digital records of heritage assets for long-term storage and future reference.	Photogrammetry, TLS/LiDAR, HBIM, GIS	Creates permanent digital databases containing geometric, historical, material, and conservation information accessible for research and management.
Disaster Risk Management	To prepare for and respond to natural or human-induced disasters affecting heritage sites.	UAV Survey, TLS/LiDAR, Photogrammetry, GIS	Supports hazard mapping, emergency documentation, rapid damage assessment, and post-disaster reconstruction planning.
Tourism and Virtual Heritage	To improve public access and interpretation through digital visualisation.	Photogrammetry, UAV Survey, TLS/LiDAR, HBIM	Enables virtual tours, augmented reality (AR), virtual reality (VR), and interactive 3D models, promoting heritage education and sustainable tourism.

4 CHALLENGES IN BUILT HERITAGE DOCUMENTATION

Although significant advances have been made in digital documentation technologies, there are still some barriers to effective implementation in the context of built heritage conservation. The processing of big data, which is common when using advanced technologies like terrestrial laser scanning (TLS), LiDAR, unmanned aerial vehicles (UAVs) and Heritage Building Information Modelling (HBIM), can be time-consuming and require high computing systems and sophisticated software. In addition, data exchange and long-term information management are difficult due to the interoperability problems between various software systems and data formats. The lack of trained professionals with skills in surveying, photogrammetry, remote sensing, HBIM and conservation practices, especially in countries with limited access to technical training, is another major problem. There is also no common standard for documentation, which leads to variations in the data acquisition, modelling process, data metadata and accuracy requirements among projects and hinders collaboration and data integration. Furthermore, digital heritage documentation also poses legal and ethical issues of data ownership, intellectual property rights, privacy, and the protection of culturally sensitive information. Overcoming those technical, institutional and regulatory challenges is crucial to the implementation of sustainable, reliable and interoperable documentation of heritage [18], [19].

Table 3: Major Challenges in Built Heritage Documentation and Their Implications

Challenge	Description	Impact on Heritage Documentation	Possible Mitigation Strategies
High Equipment Cost	Advanced technologies such as Terrestrial Laser Scanning (TLS), LiDAR, UAVs, and high-resolution cameras require substantial investment in hardware and licensed software.	Limits the adoption of digital documentation, particularly for small organisations and developing countries.	Increase government funding, promote institutional collaboration, and utilise cost-effective alternatives such as photogrammetry where appropriate.
Complex Data Processing	Processing point clouds, image datasets, and 3D models requires specialised software, high-performance computers, and technical expertise.	Increases project duration and operational complexity, delaying conservation planning and documentation outputs.	Develop automated workflows, employ cloud computing, and adopt AI-assisted data processing techniques.
Interoperability and Large Datasets	Different documentation platforms often use incompatible data formats, while large datasets require significant storage and computing resources.	Creates difficulties in data exchange, long-term preservation, and multidisciplinary collaboration.	Adopt open data standards, improve software compatibility, and implement efficient data management and compression techniques.
Lack of Trained Professionals	There is a shortage of experts skilled in photogrammetry, TLS, UAV surveying, HBIM, GIS, and digital heritage conservation.	Reduces the quality, accuracy, and effective implementation of documentation projects.	Strengthen professional training, university curricula, and interdisciplinary capacity-building programmes.

Standardisation Issues	Inconsistent documentation protocols, metadata standards, and accuracy requirements across institutions and countries.	Limits the comparability, reliability, and integration of documentation datasets.	Develop internationally accepted documentation guidelines and standard operating procedures through organisations such as UNESCO and ICOMOS.
Legal and Ethical Concerns	Issues related to data ownership, copyright, privacy, cultural sensitivity, and unauthorised use of digital heritage models.	May restrict data sharing, public access, and collaborative research while increasing legal risks.	Establish clear data governance policies, intellectual property agreements, and ethical guidelines for digital heritage documentation.

5 FUTURE DIRECTIONS IN BUILT HERITAGE DOCUMENTATION

The rapid development of digital technologies is fostering a shift in built heritage documentation from descriptive recording towards intelligent, integrated and data-driven systems appropriate for efficient conservation and management. AI is being applied more and more to automatic feature extraction, object recognition, damage identification, and semantic image and point cloud segmentation, to save processing time, boost accuracy and consistency. Another recent trend is the adoption of Digital Twins, which simulate dynamic images of the heritage buildings based on the geometric models and their real-time monitoring data, monitoring the buildings' condition continuously, predicting their maintenance needs, and assessing the potential risks. Cloud-based heritage management is also becoming more relevant for its capacity to store data safely, access remotely and share information with different actors for the study, conservation and management of large heritage data sets. In addition, the use of Heritage Building Information Modelling (HBIM) alongside Geographic Information Systems (GIS) provides a holistic solution that integrates building data with spatial and environmental information. These integrated systems have been found to improve heritage inventory management, conservation planning, disaster preparedness and sustainable decision-making. Together, these technologies will contribute to better understanding of built heritage in terms of their accuracy, accessibility and long-term management, and will aid in more effective conservation practices [20].

6 LITERATURE REVIEW

(Billor et al., 2026) [21] The integration of "digital twin (DT) and virtual reality (VR) technologies" across various disciplines has not been mapped as a single study topic, despite the fact that museum-oriented built heritage stands at the crossroads of conservation, structural evaluation, and visitor experience. Digital documentation and photogrammetric survey; VR, virtual museum, Heritage Building Information Modelling (HBIM), and new digital twin applications; AR-based museum experience and interpretation; and sustainable heritage tourism and management are the four conceptual clusters that emerge. The top two countries in terms of national output are Italy (n = 90) and China (n = 85); the top university is Universidad Politécnica de Valencia (n = 31). Communities that are experience-focused and those that are documentation-focused continue to differ. For empirical validation in case studies of stone-built museums, a three-pillar system connecting DT-based structural documentation, immersive visitor experience, and sustainable museum administration through Industry Foundation Classes (IFC) interoperability is suggested.

(Rajendran & Athira, 2025) [22] There is a significant lack of guidelines, toolkits, and approaches that should be used in this field, particularly in light of the prevalent assumptions that prevent us from obtaining the tools that conservation practice may significantly benefit from. By attempting to provide best practices for cultural heritage recording, this article aims to close this gap. It accomplishes this by looking at the different project case studies in terms of their specifications, tools used, time spent, difficulties faced, process, output, complexity and usefulness, etc. The paper attempts to develop guidelines that might be helpful for similar cases in the future by choosing five documentation projects that differ in scale, context, and purpose and analysing the lessons learned from each. Additionally, it attempts to compare best practices with available manuals from nations with strong 3D technology ecosystems.

(Kamble & Patki, 2025) [23] examines the application of photogrammetry as a crucial tool for the conservation of heritage buildings. This study highlights how crucial heritage conservation is to preserving communities' cultural narratives and architectural integrity. The study presents case examples that demonstrate the adaptability and efficacy of photogrammetry in the conservation of diverse heritage assets. The results highlight the potential of this technology to transform conservation methods and offer a framework for incorporating cutting-edge methods into conventional preservation initiatives. For the documentation, study, and conservation of heritage buildings, the application of photogrammetry provides an all-encompassing solution. Adopting such cutting-edge technology is essential to preserving our architectural legacy for future generations as challenges to cultural heritage continue to increase.

(Fellas & Demosthenous, 2025) [24] analyses traditional documentation methods and contemporary methods to investigate heritage preservation practices through sustainable documentation. Photogrammetry and 3D scanning technology work together to acquire spatial data quickly and accurately with little disruption to the place. These methods provide an integrated digital archive of architectural, historical, and material data when used in conjunction with "Heritage Building Information Modelling (HBIM)". While lowering intrusive procedures and resource consumption, this integrated approach improves accuracy and efficiency and promotes sustainable conservation practices. By using these cutting-edge, sustainable techniques, heritage preservation will be guided toward an ecologically conscious future, guaranteeing that restoration practices are knowledgeable, effective, and in line with long-term sustainability objectives.

(Rios et al., 2024) [25] learn more about how conservation professionals view the adoption of Industry 5.0 principles and supporting technologies, as well as the anticipated obstacles and the abilities required to overcome them. To gather pertinent data, a survey questionnaire was created, evaluated, and put into use. Although the importance of Industry 5.0 principles and supporting technologies is well recognised, their application in built cultural heritage conservation is still restricted, according to an analysis of the data gathered. Bridging knowledge gaps, improving training programs, and obtaining the resources required to get beyond these obstacles should be the top priorities of future projects.

(Khalid, 2022) [26] The significance of architectural heritage has grown as a result of recent global activities in world heritage forums, particularly UNESCO. The term "architectural heritage" refers to build buildings that have exceptional natural and cultural worth and need to be preserved, presented, and passed down to future generations. Six World Heritage Sites in Pakistan have been designated by UNESCO as needing preservation. In addition, natural deterioration, theft, vandalism, and other sociocultural damages are occurring at the heritage sites. The digital preservation of historic sites is one of the most advanced techniques. Among the several computer technologies, photogrammetry is the fastest and most economical technique for digital preservation. The study will concentrate on the new architectural trend of digital preservation of UNESCO World Heritage Sites. The majority of historic sites in developing nations are neglected due to a lack of funding. The study proposes photogrammetry as an affordable option for six UNESCO-listed historic monuments in Pakistan, highlights the difficulties associated with digital preservation, and promotes digital preservation as an emerging answer. It also implies that information about historic places might be digitally collected and utilised in a variety of ways to produce more revenue.

7 CONCLUSION

Documentation of built heritage has transformed from traditional survey processes, to advanced digital documentation technologies which allow for very detailed, accurate and efficient records of built heritage. Documentation has been very improved by means of techniques like TLS/LiDAR, UAV surveys and HBIM, which allow for improved conservation planning, structural assessment, restoration, digital archiving, disaster management and long-term maintenance. However, these developments have not been successful enough due to issues such as high implementation costs, complex data processing, interoperability, lack of skilled personnel and lack of standardized documentation protocols. Capacity building, international standards and better data governance will help overcome these challenges and enhance conservation practices. Moreover, new technologies, such as Digital Twins, cloud-based heritage management, and integrated HBIM-GIS platforms, are new opportunities to manage and make decisions about heritage intelligently and based on data. The ongoing development and use of them will enhance the documentation and accessibility of built heritage, as well as the nature of collaboration and the decision-making process, and thus contribute to the sustainable preservation of built heritage for future generations.

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