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Transforming architectural heritage documentation: developing integrated European recommendations for safeguarding and preservation

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The safeguarding and preservation of architectural heritage are pivotal to maintaining Europe's cultural identity, while current documentation practices remain fragmented and unevenly applied across regions. This article critically evaluates existing standards, recommendations, and best practices to identify gaps and inconsistencies in architectural documentation methodologies across European Countries. Based on this evaluation, we propose an integrated and adaptive European recommendation for architectural heritage documentation.

Cultural heritage including its tangible and intangible elements, represents historical and cultural identity of a society, which is why, it is important to be preserved for the future generations[1]. Architectural documentation plays a crucial role in preserving this heritage by offering detailed records that guide conservation efforts and mitigate risks of destruction due to natural disasters, urban development, or neglect[1,2]. The term architectural documentation broadly refers to various types of acquired and processed data related to the shape, dimensions, and geometric relationships between different elements and parts of a structure (geometrical documentation), as well as the condition of the structure, its physical properties, and its state of preservation or degradation (qualitative documentation)[3–6]. Geometrical documentation represents the object's shape for measurement purposes, and it is typically presented as site plans, sections, elevations, and three-dimensional models[7–11]. There are several survey methods that is used for heritage documentation (especially geometric documentation), and the choice of these methods depends on object size, complexity, accessibility, budget, and equipment[12] (Fig. 1). Hand measurement-based methods like calipers, measuring tapes, or rulers are typically used for measuring small objects (e.g., artifacts, sculptures) and allow for providing dimensions and relative positions of these objects, but they can become uneconomical for larger sites[12]. Terrestrial photogrammetry (also known as close-range photogrammetry) and close-range scanning (also known as terrestrial laser scanning) are widely used for both small-sized objects and medium-scale structures (such as buildings and interiors), enabling a broad range of applications[13–17]. Remote sensing and large-scale surveying techniques, including satellite remote sensing, airborne photogrammetry, UAV-based photogrammetry, and aerial LiDAR, are primarily employed for documenting medium- and large-scale objects such as archaeological sites, historic city centers, and cultural landscapes[18,19]. These methods enable efficient data acquisition over extensive areas and are often integrated with GIS platforms for spatial analysis and visualisation[13–16].

The aforementioned measurement techniques have been employed for many years in the documentation of cultural heritage sites. However, these methods are no longer used in isolation, instead, integrated approaches combining multiple techniques are now a standard practice. Technological advances, such as Building Information Modelling (BIM)[20] and 3D laser scanning/photogrammetry, have revolutionised the creation of precise records of historic structures. The combination of advantages and limitations of these methods enables the addition of semantic layers and parametric attributes, as well as integration with analytical workflows. However, this approach introduces trade-offs between parametrisation and the accurate representation of irregular heritage geometries[21,22]. Methodological studies emphasise that the key challenges of HBIM include ensuring geometric accuracy, enriching semantic content during modelling, and consciously managing heritage object[23,24].

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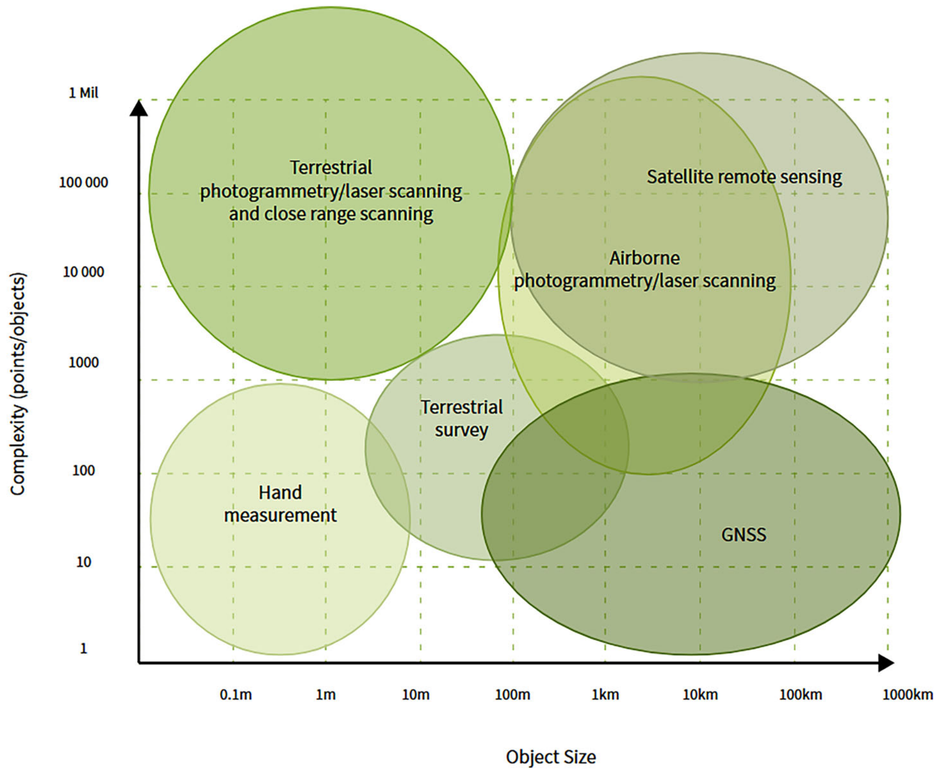
Fig. 1 | Survey techniques defined by object complexity (points captured) and size[12].



The Notre-Dame restoration exemplifies the maturity and effectiveness of reality-based 3D scanning, where a pre-fire point cloud and the CNRS digital twin became the operational foundation for reconstruction and design decisions, illustrating the critical role of preventive metric documentation in preserving formal integrity[25]. At the same time, recent research highlights a shift toward hybrid workflows combining TLS and image-based methods for HBIM utilisation. These approaches are validated by case studies from the Middle East and Europe, i.e., projects integrating multi-source data[26–28].

With the advancement of data acquisition and processing methods for creating 3D models, there is a growing need to incorporate Augmented Reality (AR) and Virtual Reality (VR) in applications related to cultural heritage documentation[29–31]. However, it should be emphasised that AR and VR visualisations are not standalone tools; they are derived from accurate digital documentation methods such as 3D scanning, photogrammetry, and HBIM models. Their primary role is to enhance interpretation, education, and stakeholder engagement, while ensuring traceability to the original source data[32].

The absence of a comprehensive, unified and widely accepted standard for architectural documentation in Europe delays consistent approaches to safeguarding cultural heritage. Existing methodologies vary widely, from traditional 2D records to advanced 3D modelling, but lack integration across disciplines. Moreover, the disconnect between tangible and intangible heritage aspects in documentation limits preservation strategies. This fragmentation risks loss of cultural authenticity, continuity, and accessibility, particularly in regions facing rapid urbanisation or environmental changes[33,34].

In recent decades, cultural heritage documentation has undergone a profound transformation, driven by integrating digital technologies into conservation practices. Foundational charters such as the ICOMOS Venice Charter (1964)[35], the London Charter (https://londoncharter.org/, 2009), and the UNESCO Historic Urban Landscape Recommendation (2011)[36] have laid the ethical and methodological groundwork for heritage preservation. However, tools like 3D scanning, GIS, and BIM become increasingly central to cultural heritage documentation[37,38]. Therefore, the existing frameworks, often struggle to keep pace with technological advancements. Newer initiatives, including Europeana's 3D digitisation guidelines (2020)[39] and national standards, attempt to bridge this gap by promoting transparency, interoperability, and sustainability. Despite these efforts, challenges remain in standardisation, legal enforcement, and equitable access to digital tools, particularly for smaller institutions.

Therefore, this study aims to evaluate current standards, recommendations, and practices in architectural documentation across Europe. Moreover, the study aims to identify gaps and challenges in harmonising approaches to cultural heritage preservation, which will result in a novel and interdisciplinary recommendations for architectural documentation that integrates advanced technologies, sustainability principles, and intangible heritage consideration while fostering collaboration among policymakers, architects, and conservationists to implement this recommendation effectively. To achieve this aim, the study will analyse several key factors essential for developing a unified and future-proof architectural documentation standard across Europe. These include technical parameters such as image resolution, point cloud density, and registration accuracy, which are critical for ensuring precision in heritage recordings. The study will also examine the standardisation of formats for images, vector drawings, and 3D models to promote interoperability across platforms and institutions. The proposed metadata requirements and validation protocols make it possible to support long-term data integrity and accessibility. They may also influence ethical documentation practices, including para-data and transparency in decision-making, which are crucial for protecting and preserving cultural heritage objects.

Establishing a unified architectural documentation recommendations would revolutionise cultural heritage preservation by ensuring consistency, enhancing accuracy, and facilitating cross-border collaboration. Such recommendations would also enable integration with sustainable urban planning, bridging the gap between historical preservation and modern development. The proposed recommendations could change current practices and address critical challenges, including climate change resilience and public engagement, to secure Europe's cultural heritage for future generations[40–42].

Fig. 2 | ICOMOS charter and declaration about cultural heritage preservation and digitalisation[20].

Evaluation of existing standards, guidelines and good practices in architectural documentation of cultural heritage across the EU

The safeguarding and preservation of architectural heritage is directly linked to using standards, recommendations, and best practices related to the acquisition and processing of documentation associated with the inventory of cultural heritage objects. In the context of cultural heritage documentation, standards[43] and norms (https://premiercs.com/blog/how-to-master-construction-drawing-standards-expert-guide-for-perfect-documentation) refer to formalised, often legally binding, frameworks that establish uniform criteria to ensure consistency, safety, and interoperability across processes and products. By contrast, recommendations[44], guidelines[45], and good practices are non-binding instruments that provide structured advice, methodological suggestions, and empirically validated approaches to enhance quality, efficiency, and decision-making. While adherence to standards and norms is mandatory to meet regulatory or technical requirements, following recommendations, guidelines, and good practices remains voluntary, offering flexibility to adapt to specific contexts while promoting professional excellence and innovation. However, the European countries don't follow the same documentation practices due to the differences in cultural contexts, technological capacity, and regulatory frameworks. Therefore, the aim of this article is to assess the current European architectural documentation practices to identify their strengths and limitations. The outcome of this evaluation will be the development of a cohesive, cross-border recommendations for architectural documentation and preservation of European cultural heritage.

Digital documentation frameworks: innovation and limitations

The ICOMOS Venice Charter (1964). The International Council on Monuments and Sites (ICOMOS) has, for many years, promoted scientific methodologies for the preservation of architectural heritage, and it is involved in the digitalisation of historical structures and sites (Fig. 2)[20].

The ICOMOS Venice Charter (1964)[35] is one of the foundational documents that has shaped global conservation practices, particularly in Europe. It highlights essential principles such as minimal intervention, preserving authenticity, and the need for thorough documentation throughout conservation efforts (ICOMOS, 1964; 1979). While the Venice Charter focuses on protecting monuments' historical and artistic value, the Burra Charter, developed in Australia, has gained international recognition for emphasising cultural significance, detailed analysis, and systematic documentation. Building on these ideas, the Nara Document on Authenticity (1994)[46] broadened the concept of authenticity to include cultural and contextual perspectives, reflecting the growing recognition of diverse heritage values worldwide.

The ICOMOS Charters are widely respected for their flexibility and ethical focus, encouraging a holistic view of conservation that brings together heritage's physical, cultural, social, and historical aspects. Their adaptability has allowed them to serve as valuable references across different countries and contexts. However, this broad approach also comes with challenges, namely, the charters offer little specific guidance on how to incorporate modern documentation technologies like 3D scanning, Building Information Modelling (BIM), and Geographic Information Systems (GIS), which are becoming essential tools in conservation today. As a result, their application has divided institutions with some embracing digital innovation, while others continue to rely on more traditional methods. Although the charters provide a strong ethical and methodological base for conservation work, updating them to reflect current practices is important by offering clearer recommendations on integrating new technologies and ensuring more consistent application.

The London Charter (2009). The London Charter for the Computer-Based Visualisation of Cultural Heritage (2009) is an important set of principles for the use of digital technologies in heritage conservation with a focus on para-data, which requires the detailed recording of all decisions, assumptions, and modifications made during the visualisation process in areas like geospatial data handling and virtual reconstruction. This emphasis on transparency ensures that any changes to raw data or the introduction of hypothetical elements are clearly documented, promoting accountability and trust in digital heritage work. The Charter's influence has significantly shaped practices in academic research, museum exhibitions, and educational initiatives. At the same time, its focus on visualisation responds to the growing demand for more engaging and accessible forms of documentation. However, despite its contributions, the London Charter has its limitations owing to being a set of guidelines lacking legal authority, which leads to uneven adoption. Moreover, it does not fully address the integration of newer technologies like artificial intelligence and advanced 3D modelling, creating a gap between its original vision and the needs of contemporary practice. However, it has inspired later initiatives, such as the Seville Principles of Virtual Archaeology (2017).

UNESCO Recommendation on the Historic Urban Landscape (2011). The UNESCO Recommendation on the Historic Urban Landscape (HUL)[36], introduced in 2011, offers a comprehensive and integrated approach to conserving historic urban areas. It focuses on documenting tangible and intangible heritage, considering urban environments' broader socio-cultural and historical contexts. By linking cultural heritage conservation with urban development and social sustainability, the HUL framework recognises the interconnectedness of urban landscapes' historical, social, and cultural elements. This approach provides a flexible model for heritage management that can be adapted to different cultural and urban contexts across Europe. However, implementing HUL has challenges, particularly in rapidly growing urban areas, where finding a balance between preservation and development demands a multidisciplinary approach. Additionally, the framework lacks specific guidance on using advanced digital tools for urban heritage documentation, leading to inconsistent application.

The Seville Principles for Virtual Archaeology (2017). The Seville Principles for Virtual Archaeology, introduced in 2017[47], offer a structured framework for applying digital technologies in archaeological research and heritage documentation. These principles highlight the importance of creating virtual reconstructions using verifiable archaeological data to ensure that digital representations remain faithful to existing evidence. By advocating for transparency in methodologies, the Seville Principles highlight the need for thorough documentation of all processes involved in creating digital reconstructions, including recording decisions, assumptions, and hypotheses, which is known as para-data that aligns with the London Charter. It should be emphasised that this document (similar to the London Charter) does not directly address the requirements related to the metric aspects of generating architectural documentation, but instead focuses on the transparent and ethical management of information in creating 3D visualisations of heritage.

The Seville Principles also promote interdisciplinary collaboration, encouraging archaeologists, digital experts, and heritage professionals to work together to enhance virtual reconstructions' accuracy and scientific rigour. They emphasise accessibility and inclusivity, urging practitioners to consider digital models' educational and cultural value for diverse audience. Recognising that digital archaeology quickly evolves, the principles also acknowledge that virtual reconstructions may change as new data becomes available.

Despite their significant contributions, the Seville Principles have substantial limitations, namely, their advisory nature means they lack enforceable mechanism, which can reduce their impact, especially in situations where financial or institutional constraints might deprioritise ethical concerns. While the principles provide strong ethical guidance, they fail to offer detailed technical methodologies, leaving gaps that practitioners must fill independently. Furthermore, the principles do not fully address integration of emerging technologies such as AI or immersive platforms (AR and VR), limiting their relevance in the fast-evolving digital heritage field.

However, the Seville Principles have played a key role in standardising ethical practices in virtual archaeology and have inspired subsequent guidelines, such as those for 3D digitisation in cultural heritage. Their focus on transparency, accountability, and evidence-based reconstructions has set an important benchmark for ethical digital documentation.

CIPA 3-by-3 Rules (1994, updated 2013). The CIPA 3-by-3 Rules (also known as Photogrammetric Capture The '3 × 3' Rules), developed by the International Committee for Documentation of Cultural Heritage (CIPA), provide a comprehensive set of guidelines for photogrammetric architectural documentation. These rules emphasise three areas: (1) geometrical rules, which govern the setup of reference control networks and photographic coverage; (2) camera rules, which include guidance on camera calibration and lens selection; and (3) procedural rules, which address the documentation of camera positioning and image metadata[48].

The first set of rules relates to the geometric conditions affecting the amount and distribution of images and how the reference control network is defined. For the control network, guidance is provided on the placement of control points or scale bars. The description of how the images are taken is divided into two cases: wide area stereo photocover and detail stereo photocover. This document outlines fundamental principles regarding the minimum overlap between stereo images, guidelines for capturing these images, and criteria for selecting an optimal distance-to-baseline ratio. These factors are critical for maximising the accuracy of 3D coordinate determination. However, despite the rapid development of the Structure-from-Motion and Multi-view Stereo methods, which use a much larger number of images taken with higher coverage and from significantly different distances and distance-to-baseline ratios, these recommendations are still applicable, as the mathematical assumptions related to the accuracy of 3D coordinate point determination do not change.

The recommendations regarding camera guidelines provide detailed information on camera properties, calibration and image exposures. Recommendations for camera properties include information on the selection and use of lenses, the format of images and the choice of resolution and storage format of the acquired images. The need to perform geometric and radiometric calibrations and those related to image selection, HDR exposure parameters, and geotagging of images was highlighted.

The final set of recommendations refers to procedural guidelines, covering aspects such as the required documentation, including diagrams illustrating camera positions around the survey site with indicated reference points, the metadata to be assigned to the images, and the appropriate methods for storing and archiving the data.

Despite their historical significance and detailed technical recommendations, the 3-by-3 Rules have become less relevant due to rapidly advancing documentation technologies, such as 3D laser scanning and UAV-based photogrammetry. A new version has been issued to adapt to the digital age[49]. While the guidelines are valuable for ensuring precision, their applicability is limited in modern contexts, requiring updates to accommodate modern technologies. At the same time, current technologies are fully capable of producing high-resolution architectural documentation that satisfies the guidelines, which should now be regarded as representing only a minimum standard when processing close-range imagery.

The Basic Principles by Europeana (2020). The Basic principles and tips for 3D digitisation of cultural heritage, published by Europeana and the EU Expert Group on Digital Cultural Heritage in August 2020[39], provide a foundational framework to support institutions engaging in digital heritage documentation and 3D digitisation. These principles highlight the importance of interoperability, sustainability, and open metadata standards to ensure long-term access and usability of digital resources. The principles encourage institutions to clearly define the purpose of digitisation, whether for documentation, conservation, or public engagement, and to select assets and use cases that align with these goals. Institutions are also urged to carefully consider whether to handle digitisation in-house or outsource it, considering costs, available expertise, and equipment.

A key emphasis is to resolve rights and copyright issues early on to ensure broad and open-access adaptation, while adhering to quality standards supported by metadata and standardised workflows. The principles promote using versatile and widely accessible data formats, such as high-resolution models or AR/VR outputs. They also stress the importance of strong data preservation strategies, including secure storage and backup systems, to protect raw and processed data. Additionally, methods like photogrammetry and laser scanning are recommended to ensure high-quality results without compromising the integrity of heritage assets.

These guidelines recognise the increasing need for professionals to develop expertise in 3D technologies to manage projects effectively, maintain quality control, and support broader digitisation efforts. However, the document lacks detailed technical methodologies, leaving institutions to seek additional resources for practical implementation.

CARARE Schema. The CARARE Schema plays a key role in standardising metadata for the digital documentation of European cultural heritage, especially monuments and archaeological sites (https://www.carare.eu/en/services/carare-aggregation-services/carare-metadata-schema/). One of its main goals is to improve data interoperability and make it easier to integrate digital resources like 3D models, photographs, and geographical data into Europeana, the European platform for cultural heritage[50]. This integration helps boost accessibility and encourages cross-border collaboration, allowing European institutions to share and access cultural heritage records more efficiently.

CARARE's strengths lie in its ability to support a variety of media types, which enrich the digital representation of heritage sites, making them more visible and accessible. By linking with Europeana, the project also opens up new opportunities for international collaboration. It helps make cultural heritage assets easier to discover, contributing to a more unified digital heritage landscape. However, CARARE's focus on digital documentation presents challenges for institutions that still rely on traditional methods, especially in regions where digital transformation is a significant challenge. Additionally, the resource-intensive nature of CARARE requires substantial technological infrastructure and expertise, creating barriers for smaller or underfunded institutions.

The CIDOC Conceptual Reference Model (CRM)—European Standard on Heritage Data (ISO 21127:2023). The CIDOC Conceptual Reference Model (CRM) is an international standard (ISO 21127:2023) that offers a comprehensive framework for structuring data and metadata in the cultural heritage sector[51]. The CRM was developed by the International Committee for Documentation (CIDOC) of the International Council of Museums (ICOM). The main goal of the standard is to improve data interoperability, enabling seamless integration and information exchange between diverse cultural heritage institutions across Europe and globally. By establishing a consistent reference model, the standard encourages uniform practices in documentation, digital archiving, and sharing of cultural heritage data. One of the key features of the CIDOC CRM is its broad applicability and flexibility to different types of cultural heritage data, ranging from physical artefacts and historical documents to digital representations and metadata records. The CIDOC CRM provides definitions and a formal structure for describing explicit and implicit concepts and relationships used in cultural heritage documentation. Its goal is to foster a shared understanding of cultural heritage information by offering a common and extensible semantic framework to which any such information can be mapped. It serves as a common language for domain experts and system developers, and as a guide to best practices in conceptual modelling.

Referring to CIDOC CRM also encompasses so-called compatible models, or application profiles, which have been developed to meet specific documentation needs. One such model is CRMdig (CRM Digital) - an ontology and RDF schema designed to encode metadata about the processes and methods involved in the production (or provenance) of digitisation outputs and synthetic digital representations, such as 2D, 3D, or animated models created using various technologies. A distinctive feature of CRMdig, compared to competing models, is its complete inclusion of the initial physical measurement processes and their parameters. Developed as a compatible extension of CIDOC CRM, it allows for querying key facts and retrieving complete descriptions encoded in the model using generic ISO 21127 terms, without needing to refer to its specific properties. In contrast, competing models are limited to computational provenance and cannot be queried using a broader standard. Nevertheless, data encoded in major competing models can be transformed into CRMdig format without losing meaning.

However, implementing this standard can be challenging for a number of institutions that may lack the available resources or technical expertise or available resources. The complexity of the standard often requires a high level of specialised knowledge and technical infrastructure, which can be a barrier to the adoptation. The financial and time commitments needed for staff training, system upgrades, and ongoing maintenance may discourage smaller organisations from fully adopting the framework.

Another limitation is its reliance on consistent and comprehensive metadata generation. While the standard provides clear guidelines for structuring data, the quality and completeness of the metadata depend on the practices of individual institutions, which can vary. Furthermore, the standard does not directly address emerging challenges in the digital heritage field, such as integrating AI-driven systems or managing increasingly complex datasets from advanced imaging and scanning technologies.

National standards and frameworks for heritage documentation

MIDAS Heritage Data Standard (United Kingdom). The MIDAS Heritage Data Standard is one of the most widely used frameworks for documenting cultural heritage in the United Kingdom[52]. It offers a standardised approach for recording and managing heritage data, promoting interoperability and enabling efficient data sharing across institutions. The framework is especially effective in integrating traditional heritage objects and digital resources like 3D models and Geographic Information Systems (GIS) data. It is invaluable for documenting tangible heritage assets, such as monuments and archaeological sites. Its flexibility ensures it can be applied across various heritage contexts, improving consistency and comparability in data management practices.

A key strength of MIDAS is its ability to support interoperable systems, facilitating integration with diverse databases and tools, and helping standardise documentation processes. However, the standard has limitations such as addressing intangible cultural heritage, namely oral traditions and cultural practices, which are vital for a holistic approach to preservation. Additionally, its implementation can be resource-intensive, requiring significant technological infrastructure and expertise, which can be a barrier for smaller or underfunded institutions.

ICCD Cataloguing Forms (Italy). The ICCD Cataloguing System is Italy's main framework for documenting architectural, archaeological, and artistic heritage, which is widely used across Southern Europe and uses a hierarchical structure of data forms to thoroughly record detailed information on the physical attributes, materials, construction techniques, historical changes, and conservation status of heritage objects and sites[53]. This approach prioritises detailed documentation, supporting condition assessments, restoration tracking, and long-term, sustainable heritage management. The system's rich metadata also helps to link individual heritage items with their broader historical and cultural contexts.

A key strength of the ICCD system is its thoroughness, ensuring that architectural and artistic features are documented precisely, making it an invaluable resource for preservation efforts. However, its complexity can pose challenges, especially for smaller institutions or those with limited resources, as it requires specialised training and expertise. Another challenge is the slow shift from traditional paper-based forms to fully digital systems, which has affected accessibility and efficiency in some regions. Although digital tools are available, their uneven adoption has limited the system's ability to fully leverage modern technology for heritage documentation.

National-level practices: evaluating standards

An analysis of national practices in cultural heritage documentation reveals varied approaches and integration levels of standards and technologies across countries such as the United Kingdom, Germany, Poland, Cyprus, Greece, and Italy. Historic England has established a high level of maturity in the UK by embedding technology-driven documentation, including HBIM and laser scanning, into legal and procurement frameworks. This approach ensures the consistent production of quality documentation, positioning the UK as a leader in heritage digitisation. In contrast, Germany lacks a unified national standard and relies on regional practices and frameworks like the Venice Charter (1964)[35]. While this flexibility fosters innovation, the absence of uniform guidelines creates inconsistencies, with authorities often referencing external frameworks like Austria's ÖNORM (2018)[54] for technical guidance. Poland has a strong legislative heritage of protection but lacks mandatory use of digital technologies, leading to variable adoption of tools like 3D laser scanning. In Greece, EU-funded initiatives like the Digital Convergence Program have digitised significant sites like the Acropolis. Still, the absence of national standards has led to inconsistent methodologies, with some Greek institutions using frameworks like the London Charter for transparency, while others, like Italy, have pioneered practices and tools through initiatives namely MiC (Ministero della Cultura) Cultural Heritage Information Systems[49]. However, regional decentralisation leads to variability, despite frequent adoption of European standards like ISO 21127:2014[51], promoting interoperability. These national practices highlight innovation and challenges in standardising documentation across diverse contexts.

Successful heritage documentation initiatives across Europe demonstrate the value of adapting frameworks to regional contexts while incorporating new technologies. In Greece, initiatives such as the Acropolis 3D Reconstruction[55] demonstrate how advanced technologies can enhance public engagement, while UAV-based photogrammetry provides efficient means of documenting large archaeological sites. Swedish use of 3D Digitec for landmarks like the Colosseum and Pompeii[56] showcases the practical application of modern technologies in cultural heritage documentation. These projects utilise VR and AR to reach global audiences, emphasising preservation and cultural knowledge dissemination. The UK uses HBIM for management projects like Edinburgh Waverley Railway Station[57] to ensure high documentation standards. Germany's commitment to precision, seen in its use of CIPA's 3-by-3 photogrammetry rules, provides detailed and replicable results. An example can be seen in the results of the Plafond3D project, in which photographs were acquired according to CIPA's 3-by-3 photogrammetric rules and the ÖNORM standard from Austria[54], enabling the generation of high-resolution documentation of the baroque ceiling paintings in the Spiegelsaal of Schloss Rheinsberg[58]. These examples illustrate how technology can enhance heritage preservation and set global standards.

However, a critical evaluation reveals several key gaps. Interoperability remains challenging, as standards lack alignment in data acquisition, processing, and storage, preventing effective cross-border data integration. This is evident in the limited compatibility between the UK's HBIM practices and the methods used in Greece and Italy. Furthermore, while 3D technologies, AI, and machine learning have advanced, their adoption remains uneven, with Italy and Greece leading high-profile projects but facing regional constraints. Existing frameworks like the London Charter often provide broad guidance without addressing regional socio-economic and technological realities, resulting in inconsistent quality and coverage. Many standards, like the London Charter and CIPA rules, are advisory rather than legally binding, leading to uneven enforcement. The lack of binding international agreements limits consistent practices and accountability. Additionally, there is insufficient awareness and training in advanced technologies, with many institutions lacking the resources for effective implementation. While Italy has led with initiatives like MiC, other countries, like Greece, still rely on ad hoc EU-funded programs, highlighting the need for more structured capacity-building to ensure the sustainability of digitisation efforts.

Methodology

This study employed a systematic review of existing standards and guidelines for architectural documentation, encompassing a diverse range of national and international documents (Table 1). The selection of documents followed a systematic review approach prioritising internationally recognised standards, EU-level recommendations, and national guidelines that are either widely adopted or recently updated to ensure representativeness across European contexts. All documents are publicly available online and were, to the authors' best knowledge, the most relevant and authoritative sources at the time of the study. Insights from this analysis informed the identification of methodological gaps and inconsistencies, which directly shaped the design of the proposed EU-wide framework. The selection process prioritised documents that were either recently updated or considered fundamental within their respective regions. Key attributes analysed included the year of publication, scope (indoor, outdoor, or both), issuing institution, and country of origin. The documents were evaluated for their technical depth and relevance to modern architectural documentation practices. The reviewed standards were assessed using a structured evaluation framework focusing on technical parameters such as data acquisition methods, spatial resolution, accuracy, metadata requirements, storage formats, and documentation outputs. The emphasis was placed on (1) Data Accuracy and Resolution: Ensuring compliance with precision requirements for architectural and cultural heritage documentation; (2) Metadata Completeness: Evaluating the extent and quality of metadata provided, essential for traceability and data reusability; (3) Compatibility with Emerging Technologies: Assessing alignment with digital tools such as photogrammetry, laser scanning, GIS, and AI-based analysis.

Emerging technologies played a central role in the analysis, particularly in shaping the development of a unified standard. Tools such as photogrammetry, artificial intelligence (AI), geographic information systems (GIS), and 3D laser scanning were identified as transformative in enhancing the accuracy and efficiency of documentation. Their integration ensures: (1) Enhanced Precision: Achieving sub-millimetre accuracies through techniques like structure-from-motion (SfM) and dense point cloud generation; (2) Interoperability: Supporting a wide range of file formats (e.g., TIFF, DNG, OBJ, E57) and metadata standards (e.g., ARCO[59], METS - https://www.loc.gov/standards/mets/, CRMDIG[60]), and (3) Scalability: Adapting workflows for varying scales and complexities of architectural projects.

This research methodology involved a comprehensive analysis of existing standards and guidelines for architectural documentation, emphasising evaluating their criteria and method against national and European frameworks. The reviewed documents (Table 1) were selected to reflect diverse practices, covering various acquisition methods (e.g., cameras, terrestrial laser scanning, photogrammetry), spatial resolutions, and metadata requirements. Evaluation criteria included accuracy metrics such as Ground Sampling Distance (GSD) ranging from 0.5 mm to 10 mm, metadata completeness for traceability, compatibility with storage formats (e.g., TIFF, RAW, OBJ, E57), and the inclusion of transformation and calibration data.

The criteria were informed by general EU standards such as ARCO and CARARE, which emphasise interoperability, metadata quality, and adherence to accuracy thresholds. Specific national practices provided additional context. Key EU directives, including the London Charter and Seville Principles, guided the inclusion of metadata and para-data to ensure replicability and transparency in digital heritage documentation.

Emerging technologies played a pivotal role in shaping the analysis. Digital tools such as photogrammetry, AI, GIS, and BIM were evaluated for their contributions to improving precision, efficiency, and adaptability in heritage documentation. These technologies facilitate sub-millimetre accuracy, scalable workflows, and compatibility with diverse heritage documentation needs. This methodology identifies best practices and highlights areas where harmonising standards and integrating advanced technologies can create a unified, robust framework for architectural documentation.

Proposed Framework

This section presents the proposed recommendations for architectural documentation within the European Union, grounded in key principles and designed to address current and emerging challenges in the field. When preparing recommendations for architectural documentation, it is essential to consider two key aspects: the size and dimensions of the documented object and the type of final architectural documentation. These factors affect the potential time required for acquiring and processing source data, the cost, and the assumed accuracy or Level-of-Detail (LoD). For this reason, recommendations have been proposed for generating documentation for the following purposes: (1) detailed 3D modelling and data used in conservation work, (2) generating BIM/HBIM, (3) VR/AR applications, (4) online publication, and (5) 3D printing, which will be described in sections "Architectural documentation for conservation purposes–3D printing".

Table 1 | List of documents reviewed in the analysis of standards and guidelines for architectural documentation

Country	No.	Year of publication/last updated	Indoor/outdoor	Institution	Document name in English	Document in native language
POLAND	1	2021	Indoor/Outdoor	National Heritage Board of Poland (Narodowy Instytut Dziedzictwa – NID)	Good practice in documenting architectural monuments with contemporary methods of digital terrestrial recording[62]	Dobre praktyki w zakresie wykonywania dokumentacji zabytków architektury współczesnymi metodami naziemnej rejestracji cyfrowej
	2	2021	Indoor	Narodowy Instytut Muzealnictwa i Ochrony Zabytków - NIMOZ	Catalogue of Good Practice for the Digitisation of Museum Objects[63]	Katalog Dobrych Praktyk Digitalizacji Obiektów Muzealnych
	3	2020	Indoor	Castle Museum in Łańcut (Muzeum - Zamek w Łańcucie)	Acquisition of source measurement data for architectural documentation (https://old.zamek-lancut.pl/pl/Aktualnosci/Przetargi,2043)	Pozyskanie źródłowych danych pomiarowych do dokumentacji architektonicznej
United Kingdom	1	2015	Indoor/Outdoor	Historic England	Metric Survey Specifications for English Heritage[64]	-
	2	2018	Indoor/Outdoor	Historic England	3D Laser Scanning for Heritage[12]	-
	3	2017	Indoor/Outdoor	Historic England	Photogrammetric Applications for Cultural Heritage[65]	-
	4	2015	Outdoor	Centre for Digital Built Britain	AEC (UK) BIM Technology Protocol[61]	-
GERMANY	1	2003	Indoor/Outdoor	Heritage Authorities Baden – Württemberg	Recommendations for building documentation[66]	Empfehlungen für Baudokumentationen
	2	2020	Outdoor/ Archaeology	Heritage Authorities Bavaria	Guidelines for the documentation of archaeological excavations in Bavaria[67]	Vorgaben zur Dokumentation archäologischer ausgrabungen in Bayern
AUSTRIA	1	2015, updated 2018	Indoor/Outdoor	Austrian Heritage Authorities	Recording and documentation of buildings and outdoor facilities Part 2: As-built and building recording of listed objects[54]	ÖNORM A6250-2 Aufnahme und Dokumentation von Bauwerken und Außenanlagen Teil 2: Bestands-und Bauaufnahme von denkmalgeschützten Objekten
ITALY	1	2020	Indoor/Outdoor	Istituto Centrale per il Catalogo e la Documentazione (ICCD)	Guidelines for 3D documentation of cultural assets[53]	Linee Guida per la Documentazione 3D del Patrimonio Culturale
European Union	1	2022	Outdoor	European Commission	Study on quality in 3D digitisation of tangible cultural heritage (https://digital-strategy.ec.europa.eu/en/library/study-quality-3d-digitisation-tangible-cultural-heritage)	—
	2	2021	Indoor/Outdoor	Expert Group on Digital Cultural Heritage and Europeana	Basic principles and tips for 3D digitisation of tangible cultural heritage for cultural heritage professionals~~and~~ institutions and other custodians of cultural heritage[39]	—
European Union (HORIZON 2020)	1	2019	Indoor/Outdoor	Universita Degli Studi Di Ferrara (coordinator)	Inclusive Cultural Heritage in Europe through 3D semantic modelling (INCEPTION EU project https://cordis.europa.eu/project/id/665220)	—

Table 2 | Proposed Recommendations for Architectural Documentation in the EU

Category	Criteria/parameter	Proposed standard	Proposed implementation
Acquisition	GSD for orthoimages[54,65]	1 mm to 10 mm depending on scale (e.g., 1:10 −>1 mm, 1:100 ->10 mm).	Scale-based GSD requirements for consistency.
	Resolution for images[39,63] (https://digital-strategy.ec.europa.eu/en/library/study-quality-3d-digitisation-tangible-cultural-heritage)	A minimum of 24 mp camera; 50 mp is recommended for detailed elements.	Mandate the use of calibrated sensors for high-resolution imaging.
	Point cloud density[12,62]	Minimum 9 points/cm² for high-detail recording; reduced density (e.g., 3–5 points/cm²) for less detail.	Define density ranges based on project requirements.
Accuracy	Registration accuracy[62]	Relative accuracy: ≤ 2 mm; absolute accuracy: ≤ 10 mm for spatial alignment.	Use validation workflows to ensure registration meets standards.
	BIM level of detail (LOD)[61]	LOD400 to LOD600 depending on project scope (e.g., LOD400 -> geometry; LOD600 -> detailed interiors).	Follow open BIM standards such as IFC 2.0 for interoperability.
	Tolerances for vector drawings[66,67]	Scale-based tolerances (e.g., 1:50 -> ±1.5 mm, 1:100 -> ±3 mm).	Define drawing tolerances based on intended use (e.g., conservation, reconstruction).
Metadata	Required metadata elements[50]	EXIF/IPTC metadata for images; detailed sensor metadata for TLS/photogrammetry; para-data for BIM.	Develop EU-wide templates to ensure metadata consistency across systems.
Formats	Image formats[49,63]	Use tiff (8/16-bit), raw, and jpeg for imaging; ensure compatibility with metadata standards.	Require standard formats for submission to archives and heritage repositories.
	Point cloud formats[12,67]	Use e57, pts, las/laz for TLS; obj, stl, ply for 3D models.	Ensure software interoperability and adherence to open-source formats.
	Vector and orthophoto formats[66,67]	Use DWG, DXF, SVG for vector files; GEOTIFF for orthophotos.	Enable GIS and CAD integration for advanced heritage analysis.
Scale	Documentation scale[66,67]	Mandatory scales: 1:10, 1:20, 1:50, 1:100, depending on the project.	Ensure uniformity in scale for drawings, and orthoimages.
Validation	Quality assurance[66,67]	Require calibration reports, registration reports, and processing logs for validation.	Validate outputs against EU accuracy and metadata standards.
Storage	Long-term preservation formats[49]	Use non-proprietary formats: i.e. raw, tiff, e[57], obj.	Align with fair principles for digital heritage.
Ethical documentation	Para-data requirements[47] (https://londoncharter.org/)	Include methodological transparency and decision-making documentation.	Mandate the use of para-data templates during digital reconstruction and modelling.
Training	Professional competency levels[50,59,65]	Adopt EU-wide certification programs for heritage professionals.	Implement training curricula for TLS, BIM, and metadata management.
Collaboration	Cross-border standards harmonisation[39,50]	Facilitate interoperability using EU metadata schemas (e.g., CARARE, cidoc-crm).	Develop cross-border documentation protocols with multi-lingual access to guidelines.

The recommendations outlined in Table 2 focus on essential criteria such as acquisition methods, accuracy metrics, metadata requirements, and formats for long-term data storage. For example, the acquisition standards specify scale-based Ground Sampling Distance (GSD) ranges to ensure project consistency, with minimum camera resolutions and point cloud densities set to guarantee high-quality imagery and spatial data. The accuracy standards propose stringent tolerances for spatial alignment and detailed modelling, with validation processes to ensure adherence to EU directives. Additionally, the framework emphasises the integration of BIM, the use of non-proprietary storage formats, and the inclusion of para-data for enhanced methodological transparency.

When referring to architectural documentation, it is essential to distinguish between the source data used to generate a specific form of documentation and the final architectural documentation. The raw data acquired during the inventory process and archived in the repository comprise the following components: a high-resolution point cloud, serving as the foundational dataset including assigned RGB values and intensity, provided in the native format of the scanning device; photogrammetric images (in RAW or TIFF format) with calibration file of the employed camera and metadata to ensure geometric accuracy; reference data of the benchmark points georeferenced to the national coordinate system; and supplementary photographic records captured with an external non-metric camera, intended for visual reference and texturing purposes, preserved in TIFF or RAW format.

When considering proposed recommendations for the required accuracies related to specific tasks involved in the inventory and documentation of cultural heritage, it is necessary to define the minimum requirements. The detailed description of these requirements is provided in Sections "Architectural documentation for conservation purposes–3D printing".

Architectural documentation for conservation purposes

When preparing architectural documentation for conservation purposes, it is essential to consider the specific objectives of the work. Such documentation should be created using integrated measurement techniques based on terrestrial laser scanning and photogrammetric techniques, ensuring the accuracy required for typical conservation works, such as preserving wall paintings, assessing materials needed for filling in missing elements, and other restoration activities. Therefore, the minimum requirements should be divided into architectural details and heritage objects. This division is driven by the nature and characteristics of the documented heritage objects, the geometric complexity of architectural details, and the type of 3D documentation used. For example, when preparing vector drawings of entire façades with a large number of geometric ornaments, applying the exact minimum requirements for the level of detail as those used for individual architectural details would result in excessive data density, significantly increased processing time, and disproportionately high costs without improving the usability of the documentation for its intended purpose. For this reason, the appropriate selection of the documentation type and its parameters is critical to guarantee the accuracy of the recorded data and its interoperability, scalability, and long-term usability within heritage management systems.

When generating *orthoimages* of walls, façades, polychromes, ceilings, and floors, the resolution should not be lower than 5 mm/pix for decorated sections and 10 mm/pix for geometrically simple objects. Regarding architectural details, the resolution should not be worse than 1 mm/pix. All orthoimages should be saved in a lossless TIFF format with a georeferencing file.

Elevation vector drawings should be produced in CAD and PDF formats at scales ranging from 1:50 to 1:10, depending on the nature of the documentation. For masonry, brick, stone, concrete, and similar structures, a scale no smaller than 1:50 is recommended; for wooden buildings, the maximum recommended scale should be 1:20, with 1:50 being appropriate only in exceptional cases. The elevation drawings should depict all wall views of the structure. In buildings with complex forms, views of walls "concealed" by other building elements should be included in the corresponding cross-sections. It is crucial to mark any defects, damages, cracks, or dampness on the elevations. Creating a separate drawing showing the defects may be advisable in some cases. Elevation drawings should, at least partially, include visible building elements such as bricks, stones, roofing materials, etc.

Sections and floor plans of the building and its floors should be prepared at scales ranging from 1:50 to 1:20 (1:100 may be used in justified cases), in CAD and PDF formats. For monumental buildings, the scope of the documentation should include all floors, the roof structure, and the roof plan. The level of horizontal sections should be drawn one meter above the floor. However, slight deviations are permissible to provide a more complete representation of all the building's elements and fixtures.

Vector drawings of architectural details should be created at a scale no smaller than 1:5, with more detailed drawings prepared at 1:2, 1:1, or 2:1 scales.

The 3D model in MESH structure should exhibit surface accuracy not lower than 1 cm/px for architectural objects and 0.5 cm for small architectural elements such as details or sculptures. During the photogrammetric data acquisition process, it is crucial to maintain an adequate distance from the subject to ensure the accuracy thresholds are met. The model does not require a closed structure; it must be free of defective or duplicate triangles or vertices. For archival purposes, the model should be exported to obj, stl, ply formats at its highest resolution, reflecting the maximum number of vertices obtained during the point cloud generation process and vertex colour data.

BIM/HBIM applications

Building Information Modelling (BIM) integrates 2D and 3D geometry, non-geometric information, and associated documentation and data. Typically, a BIM model is initiated with the geometric components. The model is assembled using existing survey data for existing structures, including heritage buildings. Relevant BIM elements, such as walls and windows, are selected, adjusted to the dimensions from the survey data, and placed accurately.

3D geospatial datasets, such as point clouds obtained from laser scanning, serve as a critical resource for BIM. These datasets capture extensive, high-resolution data from all visible surfaces of the structure, often including colour information, and form a reliable foundation for generating 3D geometry within a BIM framework. "Scan-to-BIM" workflows involve creating, manipulating, and positioning BIM components directly referencing the point cloud data.

The scope of scan-to-BIM varies depending on project needs. The result is often described as "BIM-ready," signifying a 3D model consisting of native BIM components that represent the geometry of the existing structure. This model can then be enhanced with additional information and data, linked to the appropriate BIM elements, whether components or spaces.

When developing HBIM models, utilising LOD600—As Built is essential: A precisely modelled representation of the constructed object, including any construction irregularities or eccentricities. For visualisation purposes (or with lower detail), it is recommended to use LOD400—Specific: a specific object, sufficiently modelled to identify type and component materials with accurate dimensions. This level represents a production or preconstruction "design intent" object suitable for procurement and cost analysis. Alternatively, LOD500 – For Construction / Rendering: a detailed, accurate, and specific object of the construction requirements and building components, including specialist subcontract geometry and data, should be used. This level includes all necessary sub-components adequately represented to enable construction and is used when a 3D view at a sufficient scale deems the detail required due to the object's proximity to the camera[61].

VR/AR and online publication applications

For visualisation and online presentation purposes, the model, following the retopology process (reduction of vertex count), should be exported to a file in .obj or .fbx format with generated UV coordinates (one UV map) and a complete set of textures. The maximum vertex count is dependent on the capabilities of real-time visualisation engines or online 3D file browsers. For instance, as of October 2022, the optimal vertex count for smooth operation for the Sketchfab online 3D file viewer is no more than 40 million triangles (https://sketchfab.com/blogs/community/introducing-massive-by-sketchfab-alpha/).

The model's texture should include images in an uncompressed format (TIFF, TGA, PNG) with a resolution of 8192×8192 pixels and a colour depth of 8 bits per channel or higher. The set of textures generated through photogrammetry typically consists of a colour map, a normal map conveying information about micro-surfaces, a displacement map (optional), and an ambient occlusion (AO) map (optional). A model may have multiple texture sets, but each must have UV coordinates (a single UV map) supporting one or more images/texture sets.

3D printing

Ensuring 3D models are optimised for printing is critical to avoid defects and disturbances in the printing process. The version of the model prepared for 3D printing must be "a closed", watertight structure, ensuring there are no holes or gaps in the mesh. The 3D model should only consist of triangular polygons, as triangles offer greater stability and precision in representing surfaces during printing. The model must be fully optimised to ensure it is print-ready, requiring no further adjustments such as correcting non-planar geometry or reorienting surface normals.

Although texture and colour mapping are not essential for 3D printing, geometric accuracy is critical. The model must reflect the intended dimensions and structural details with precision. It should be properly scaled to the desired print size and designed to withstand the physical demands of the printing process. In some cases, this may include the addition of structural supports for overhangs, adjustments based on the properties of the chosen print material, or fine-tuning the resolution to match the printer's capabilities. The final output should be practical and user-friendly, requiring minimal post-processing before use.

Discussion

The proposed ecomendations for architectural documentation within the European Union marks a substantial step forward in heritage management, offering a comprehensive and integrated approach designed to modernise the field. Specifically, this recomendations addresses critical methodological gaps observed in current practices, such as a lack of interoperability between national standards and data formats, the absence of unified accuracy thresholds and metadata requirements, and insufficient integration of intangible heritage aspects. By introducing harmonised criteria and cross-border protocols, this recomenadtions ensures consistency, comparability, and long-term usability of heritage documentation across the EU. Prioritising principles such as holistic integration, interoperability, and sustainability promotes the diverse cultural landscapes of Europe and adapts to ongoing technological and environmental shifts. The recommendation includes clear guidelines for documenting structural and material characteristics, sets metadata and digital archiving standards, and introduces cross-border collaboration and data exchange tools.

Impact analysis

The proposed recommendation offers the potential to reshape heritage management by addressing documentation's technical and methodological challenges. Incorporating advanced digital tools, such as photogrammetry, laser scanning, and Building Information Modelling (BIM), enables the creation of accurate, detailed digital records that support conservation, reconstruction, and analysis of cultural heritage. These records enhance both the preservation and interpretation of historic sites and structures. In addition, the recommendation's emphasis on metadata standards and paradata promotes transparency and accountability, allowing professionals to track decision-making processes and share findings more effectively. Its commitment to interoperability ensures that data can be integrated smoothly across existing systems and international collaborations. By embedding sustainability metrics into documentation practices, the recommendation supports the EU's broader environmental objectives, encouraging low-carbon and energy-efficient approaches to digital heritage work.

Challenges

Significant challenges could also affect the implementation of the proposed recommendations. Limited financial resources, whether for upgrading infrastructure or investing in professional development, will likely be a significant hurdle, especially for smaller institutions. Adopting advanced digital tools means purchasing new equipment, acquiring specialised software, and providing ongoing training, all of which require funding that may not always be available. On the technical side, data interoperability, storage demands, and processing requirements could create additional pressure. Beyond practical concerns, there may be resistance from professionals who are more comfortable with traditional documentation methods and may view digital approaches as unfamiliar or unreliable. Addressing these challenges will require coordinated efforts between policymakers, funding organisations, and training providers to build capacity and encourage a broader shift across the sector.

Existing frameworks developed by organisations such as ICOMOS, ARCO, and CARARE typically address specific aspects of documentation, including accuracy thresholds or file formats, but they often lack a fully integrated, cross-border approach. However, the proposed recommendations integrate the established methodologies and tools such as BIM, photogrammetry, and standardised metadata into a cohesive and adaptable strategy for architectural documentation management. Their focus on non-proprietary formats and alignment with EU-wide metadata standards strengthens long-term preservation and enhances interoperability, thereby addressing gaps not currently covered by existing practices. Furthermore, the integration of environmental sustainability criteria, aimed at reducing the carbon footprint of digital heritage projects, introduces a dimension that is rarely considered in current documentation practices.

The diversity of documents reviewed (from ethical guidelines such as the London Charter and Seville Principles to metadata standards like CIDOC CRM and technical best practices such as CIPA 3×3 Rules) reflects the fragmented nature of current heritage documentation practices. This heterogeneity is intentional, as each category addresses a critical dimension of documentation: transparency and accountability, interoperability and long-term preservation, and technical accuracy in data acquisition. By integrating these complementary elements, the proposed framework responds to the absence of a unified European standard, offering a harmonised approach that consolidates ethical, technical, and procedural requirements into a single, coherent recommendation.

Conclusions

This article aimed to critically evaluate the existing practices for architectural heritage documentation and propose an integrated and adaptive set of recommendations to address the fragmentation and inconsistencies in current practices across Europe. This study identified key methodological gaps by comprehensively analysing international frameworks and best practices, including MIDAS, ICCD, and the ICOMOS charters. The proposed recommendations aim to establish a unified European incorporating cutting-edge digital technologies, such as Building Information Modelling (BIM) and 3D scanning, while embedding sustainability principles and a holistic view of tangible and intangible heritage.

The successful implementation of the proposed recommendations will require coordinated engagement from policymakers, architects, and conservation professionals across the sector. Policymakers are critical in embedding these recommendations into national and EU-level regulations, ensuring legal enforceability and providing funding mechanisms for digital heritage initiatives. Architects and engineers should be involved in adapting the technical specifications such as accuracy thresholds, metadata standards, and BIM integration into practical workflows for conservation and restoration projects. Conservation specialists and heritage managers are essential for aligning documentation practices with cultural significance, authenticity principles, and ethical guidelines, ensuring that technological solutions respect heritage values. Additionally, IT professionals and data managers should oversee digital archives' interoperability, long-term storage, and cybersecurity, while academic and training institutions can develop training programs to build professional capacity. Finally, public and community stakeholders should be engaged through participatory platforms and open-access repositories, fostering transparency and inclusivity in heritage preservation. This multi-level engagement ensures that the proposed framework is technically robust and socially and institutionally sustainable across Europe.

To ensure effective implementation, the proposed recommendations encourage the coordinated action among policymakers, heritage institutions, and stakeholders, which could lead to EU-wide regulations essential to standardise digital formats, metadata schemas, and quality assurance protocols, thereby ensuring consistency and comparability among national heritage repositories. Additionally, there is an urgent need to invest in professional training and certification programmes that enhance the capacity of heritage professionals to engage with new technologies and methodologies. Adequate funding from both public and private sectors is also critical to support the adoption of digital tools, sustainable practices, and ongoing research in the field.

These recommendations promote energy-efficient solutions in heritage documentation and preservation. Moreover, international cooperation, particularly with the United Kingdom and global organisations such as UNESCO, can further strengthen implementation and promote shared learning, contributing to harmonising global heritage standards.

The proposed recommendations represent a transformative step for architectural heritage documentation in Europe and beyond. By bridging technological innovation with ethical and sustainable preservation practices, this framework offers a path forward that ensures cultural heritage is accurately documented, effectively safeguarded, and made accessible for future generations in an inclusive and resilient manner. Future research should focus on integrating advanced technologies such as artificial intelligence, machine learning, and immersive solutions (AR/VR) into heritage documentation workflows. Additionally, longitudinal studies will be essential to evaluate the long-term effects of implementing unified documentation standards across diverse institutional and regional contexts. These directions aim to foster sustained interdisciplinary collaboration and drive innovation in cultural heritage documentation.

Data availability
All materials used are available in the articles listed in the references section.

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Author contributions
J.M., P.K., and A.G. organised the conceptualisation of the idea and the methodology employed in this paper. After that, J.M., M.M., P.K., A.B., M.H., A.A., and K.C. worked on critically evaluating the existing standards and documents. The original writing and draft preparation J.M., P.K., A.G., and D.Z. All Authors reviewed the manuscript.

Competing interests
The authors declare no competing interests.

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