APPLICATION OF ADVANCED TECHNOLOGY IN ARCHITECTURAL HERITAGE CONSERVATION: EXPERIENCES FROM FRANCE AND DIRECTIONS FOR DA NANG CITY

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Abstract - The preservation of architectural heritage plays a crucial role in maintaining historical, cultural, and artistic identities, particularly in the context of urbanization and environmental changes today. France, with its rich architectural heritage and advanced preservation techniques, serves as an exemplary model in this field. This study aims to achieve two objectives: first, to introduce modern preservation methods currently applied in France and second, to propose suitable directions for architectural heritage preservation in Da Nang city. Based on field surveys of notable landmarks such as Notre-Dame Cathedral in Paris, the historic districts of Aix-en-Provence, and Marseille, the authors analyze the technologies being implemented and draw lessons from these experiences. Based on these findings, the study suggests technological solutions to enhance the effectiveness of preservation efforts and promote the sustainable development of architectural heritage in Da Nang city.

Key words - Heritage conservation; Science and technology; Architecture; Archaeology; Vietnam; France**.**

1. Introduction

1.1. Definition

The UNESCO convention concerning the protection of the World cultural and natural heritage (1972) defines cultural heritage as: *"Monuments, groups of buildings, and sites with outstanding universal value from the point of view of history, art or science."* [1].

According to Article L111-3 of the French Heritage Code, *"Historic monuments are buildings, in whole or in part, that are classified or registered on the list of historic monuments because of their exceptional character or their historical, artistic, or scientific value."* [2].

Thus, based on the definitions provided by UNESCO and French law, architectural heritage is not limited to ancient buildings but also encompasses significant historical, cultural, and artistic values. It may include grand castles, solid military fortifications, or urban districts marked by the passage of time. Each structure tells a story of the past, reflecting the evolution of society and construction techniques through various historical periods. The preservation of architectural heritage not only safeguards cultural identity but also creates opportunities for research, education, the promotion of heritage values, and contributes to sustainable development.

1.2. The importance of architectural heritage conservation

Architectural heritage holds immense historical, cultural, and artistic value and must be protected in accordance with the spirit of the UNESCO Convention. Preservation also plays a vital role in economic and social development. In Da Nang, heritage structures reflect cultural intersections but are facing increasing pressure from urbanization. Without appropriate measures, many of these sites are at risk of deterioration. Therefore, it is essential to apply modern technologies and develop long-term conservation strategies to ensure the sustainable preservation of heritage.

1.3. Objectives

There are two main objectives of the study as follows:

First: to introduce and update advanced architectural heritage conservation methods (solutions) currently being applied in France;

Second: to propose appropriate conservation directions for the context of Da Nang city.

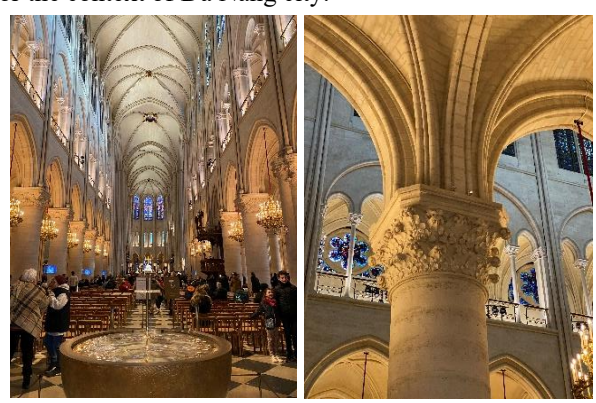

Figure 1. *After the fire in 2019, Notre-Dame Cathedral in Paris has become one of the most prominent examples in the world of applying advanced technology in the conservation and restoration of architectural heritage. (source: photograph by the authors, December 2024)*

1.4. Research methodology

The authors adopt a qualitative research approach combined with case study analysis through field observations at several representative heritage sites in France (Paris, Marseille, Aix-en-Provence). This is complemented by the synthesis and analysis of secondary data from international organizations (UNESCO), French professional agencies (Ministry of Culture, National Heritage Institute), and related academic studies. Based on a comparison with the practical context of Da Nang City,

the study proposes applicable and feasible technological solutions to enhance the effectiveness of architectural heritage conservation at the local level.

2. The process and conservation solutions for architectural heritage in France

France possesses tens of thousands of rich architectural monuments, ranging from medieval castles, Gothic-style churches, to Renaissance buildings recognized by UNESCO and the Ministry of culture. A strict heritage law system, which defines the levels of protection and management for monuments, combined with financial resources and experienced experts, has helped France maintain and restore this vast heritage. France has also pioneered the establishment of research institutes, training schools, and technical procedures for conservation, a legacy of thought and practice that continues to be upheld and developed.

2.1. Heritage conservation integrated with technology

2.1.1. Heritage classification and condition assessment

According to Article L.621-1 of the Code du Patrimoine, structures of historical, artistic, or scientific value can be classified or listed as "Monument historique" (Historical Monuments) [3]. The assessment process includes inventory, condition surveys, archival research, and digital imaging surveys (3D laser scanning, photogrammetry), following the guidelines of the National Heritage Institute (INP) in the “Guide méthodologique: Diagnostic du bâti ancien” [4].

Figure 2. *Not only churches, castles, or ancient palaces, but also modern buildings (such as the Cité Radieuse by Le Corbusier), if possessing exceptional value, can also be classified. (source: photograph by the authors, August 2024)*

The Cité Radieuse building, designed by architect Le Corbusier in Marseille, has been granted special legal protection by the state since it was listed as a "Monument historique" in 1986, along with technical and financial support for any processes involving alteration, repair, restoration, or rehabilitation.

2.1.2. Survey and conservation planning

According to the circular dated March 15, 2019, issued by the French Ministry of Culture [5], the restoration of architectural heritage is carried out by a team of specialists including a chief conservation architect (*Architecte en Chef des Monuments Historiques*), a heritage engineer, and an archaeologist. The process relies on the results of material diagnostics (XRF and Raman spectroscopy), structural assessments (pulse ultrasonic testing), and moisture-salt analysis to compile a restoration file (*Dossier de restauration*). In addition, technologies such as 3D printing and augmented reality (AR) are currently integrated in practice to enhance the effectiveness of conservation work.

Figure 3. *The technical team is conducting a survey, assessing the current condition, and collecting samples at the building located at No. 6 Espariat street, Aix-en-Provence. (source: photograph by the authors, March 2025)*

The expert team carries out an assessment of the current condition and retrieves decorative elements (such as bricks, stones, or ornamental materials) from the structure in order to study their material composition and fabrication techniques, with the aim of accurately reproducing them during the restoration process.

These samples are taken to the laboratory for analysis to determine the chemical, physical, and structural composition of the materials. The goal is to ensure that the replacement materials used in the restoration process will be compatible with the original ones.

2.1.3. Application of technology in design and restoration

The use of technology in architectural heritage conservation in France is specifically regulated in the guidelines and standards set by heritage management authorities. The national heritage institute has provided guidance on the methods of using technology for surveying, diagnosing, and conserving heritage sites through documents such as the “*Guide méthodologique: Diagnostic du bâti ancien”* [6].

2.1.4. Maintenance and protection of heritage sites after restoration

The French Ministry of Culture has issued guidelines for the maintenance and monitoring of heritage sites, including the development of maintenance plans and the monitoring of the condition of these sites. These guidelines emphasize the importance of applying technology in the protection and preservation of cultural heritage sites.

2.2. Advanced conservation technologies

In the context of many architectural heritage sites facing the risk of deterioration due to time, climate change, and urbanization pressures, the application of advanced technologies in conservation work has become increasingly urgent. In France, digital technologies and new materials are not only widely deployed but also play a key role in the digitization, monitoring, and restoration of historical architecture. Below are the prominent technologies currently being applied in France.

2.2.1. 3D Laser scanning technology

One of the most advanced technologies currently being widely applied in France for surveying, conserving, and restoring architectural heritage is 3D laser scanning. This technology enables highly accurate three-dimensional reconstruction of structures with an error margin of just a few millimeters, effectively supporting damage assessment, technical documentation, and heritage communication. The process involves three main steps: preparing the survey, conducting the scan to collect point cloud data, and processing the data using specialized software such as FARO Scene or Leica cyclone. A notable example of its application is the Notre-Dame Cathedral in Paris, where 3D laser scanning has helped overcome the limitations of traditional manual surveying methods, which are time-consuming and prone to errors.

Professor Andrew Tallon pioneered the use of 3D laser scanning to "delve into" the mindset of medieval builders. At Notre-Dame Cathedral, he set up scanners at over 50 locations inside and around the cathedral, collecting over a billion data points [7].

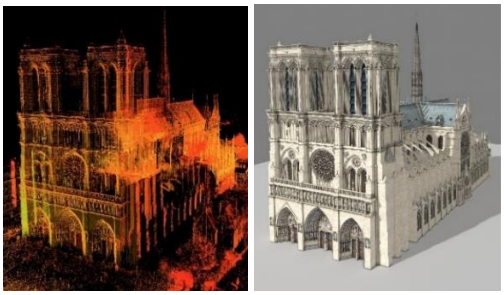

Figure 4. *The point cloud (left image) and the rendered model (right image) are the results of Andrew Tallon's work on the Notre-Dame Cathedral project since 2010. (source: Andrew Tallon-Art Graphique et Patrimoine [7])*

2.2.2. Photogrammetry

Photogrammetry, or image-based surveying, is an advanced 3D digitization technology widely used in architectural heritage conservation in France. By capturing thousands of images from various angles, it accurately recreates the shape and surface of buildings, effectively supporting research and restoration. When combined with 3D laser scanning, it enables non-contact surveys with high precision, helping to create digital records and analyze cracks, deformations, and deterioration over time.

2.2.3. Heritage building information modeling (H-BIM)

Heritage building information modeling or “BIM du patrimoine” in French, is a specialized branch of Building Information Modeling (BIM) designed to serve the digitalization, management, and conservation of historical heritage buildings. H-BIM not only creates 3D models of ancient structures but also integrates information about materials, traditional construction techniques, current conditions, and the history of interventions, assisting experts in making accurate decisions during the restoration and conservation process.

The input data for H-BIM comes from condition surveys, extracted from 3D laser scanning technology and digitized by experts from hand-drawn sketches. The data is processed using digital drawing software such as AutoCAD and Revit.

H-BIM also plays a key role in generating technical drawings for restoration and reconstruction projects. Additionally, it allows engineers, architects, M&E system engineers, archaeologists, and regulatory bodies to access detailed data about the building.

In the restoration project of Notre-Dame Cathedral after the fire in 2019, the 3D laser scans previously carried out by architect Andrew Tallon provided detailed data on the shape, dimensions, and structure of the cathedral, which helped recreate the building through an H-BIM model for the restoration process [8].

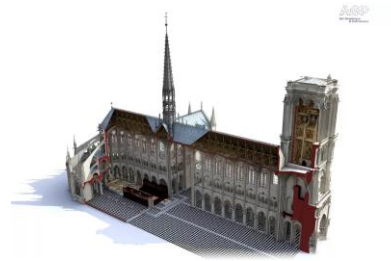

Figure 5. *For over 20 years, Art Graphique et Patrimoine has created a complete model of Notre-Dame Cathedral. (source: Andrew Tallon-Art Graphique et Patrimoine [7])*

2.2.4. Archaeological technologies

Modern archaeological technologies such as XRF and Raman spectroscopy allow for the identification of chemical compositions without causing damage, thereby aiding in the selection of appropriate conservation methods [9]. Ultrasound pulse technology is applied to assess the internal structure of heritage sites, detecting cracks or damage without physical intervention [10]. In addition, environmental analysis aimed at controlling humidity and soluble salts also plays a crucial role in long-term preservation. These technologies provide accurate data, supporting the scientific and sustainable protection and restoration of heritage sites.

2.2.5. Virtual Reality (VR) and Augmented Reality (AR)

VR technology enables the virtual reconstruction of architectural works, allowing experts to analyze and present heritage sites with high visual clarity. Meanwhile, AR overlays virtual content onto real-world environments to enhance interpretation and interaction. Both technologies contribute to heritage promotion, education, and engaging younger generations in conservation efforts.

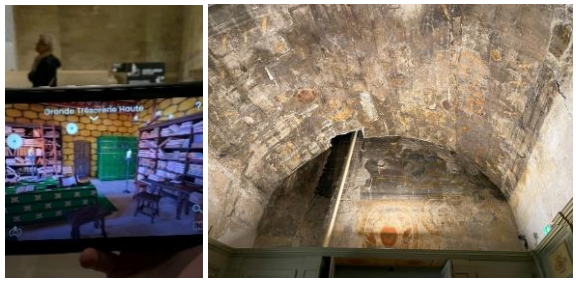

Figure 6. *Through 3D simulation and the application of AR technology, visitors are able to visualize the spaces of rooms at the Palace of the Popes that were destroyed by fire. (source: photograph by the authors, September 2024)*

Palace of the Popes in Avignon, a UNESCO World Heritage site, is a notable example. Visitors are provided with a HistoPad device, which is a touchscreen tablet integrated with AR technology, to explore the interior spaces of the palace, recreated in the style of the 19th century. The HistoPad offers 360° visuals, interactive maps, and detailed simulations of furniture and artworks, vividly reconstructing the royal ambiance.

3. Lessons learned from the study of heritage architecture conservation processes and solutions in France

3.1. Lessons from the heritage architecture conservation model in France

France's model for architectural heritage preservation stands out for its strict legal framework, effective coordination among management agencies, and its emphasis on integrating conservation with sustainable development. The country not only applies advanced technologies to accurately reconstruct heritage structures but also maintains the vital role of traditional techniques carried out by skilled artisans, helping to preserve cultural values and pass down craftsmanship to future generations. This combination of modern technology and traditional skills creates a comprehensive and sustainable approach to heritage conservation.

Figure 7. *Nicolas Orselly is a stonemason and technical instructor, providing training at the Saint-Nicolas fortress restoration site in Marseille. Under his guidance, visitors can learn and carve stone themselves at the actual heritage site. (source: Citadelle de Marseille website)*

Figure 8. *The representative architectural work Palais Longchamp – listed in 1999 (left image) and the door of an old house in Marseille are among the sites that have been damaged. (source: photograph by the authors, March 2024)*

France possesses a strong network of experts, researchers, and scientific organizations, along with robust financial mobilization capacity—all of which contribute significantly to the preservation and development of heritage sites. Its modern public transportation system facilitates heritage tourism, generating substantial revenue for both the state budget and conservation funds. However, violations of heritage sites still occur in some areas due to inadequate security and low public awareness, underscoring the need for stronger management and monitoring mechanisms.

With all the factors outlined in the research and presentation above, the authors believe that the current heritage conservation model in France can provide valuable lessons, not only helping to protect historical values but also creating a sustainable foundation for future generations.

3.2. The potential for applying technology in heritage conservation and the challenges in Vietnam

Currently, the application of technology in architectural heritage conservation in Vietnam is gradually becoming an important trend, helping to enhance the effectiveness of preserving and restoring historical monuments and promoting the cultural value of architectural works. However, despite many opportunities, there are also significant challenges in implementing and applying these technologies.

3.2.1. The potential for applying technology in architectural heritage conservation

Vietnam holds great potential for applying advanced technologies in cultural heritage preservation, especially with the growth of digital technology and artificial intelligence. With a well-coordinated strategy, modern technologies currently used in France can be effectively implemented in Vietnam. These technologies support digitization, mapping, monitoring, site reconstruction, and community education. Some heritage sites, such as Kien Trung Palace, have already been 3D scanned for accurate restoration. VR and AR technologies are also being used in museums to recreate historical spaces, offering viewers an immersive and interactive experience.

Figure 9. *The 3D mapping show recreating the history of Đà Nẵng serves as a clear example of applying technology to promote the value of urban architectural heritage, while also contributing to raising public awareness of history and heritage conservation. (source: Da Nang Museum, April 30, 2025)*

Currently, architectural heritage conservation projects in Vietnam are still being researched and implemented. Technology based conservation initiatives have also helped raise public awareness of the value of heritage. Through the strong development of media, the introduction of these technologies via exhibitions, mobile applications, and educational programs at museums has attracted significant public interest, especially among the younger generation.

3.2.2. Challenges in applying technology in Vietnam

In any scientific field, the application of advanced technology and the use of modern equipment in architectural heritage conservation require significant investment. Aside from colonial architectural heritage concentrated in major cities, there are also many other heritage structures distributed across smaller provinces and towns. However, local conservation budgets remain limited, and infrastructure for storing heritage data is often inadequate and lacks national integration.

Technology based conservation demands collaboration among heritage experts, archaeologists, architects, engineers, software developers, and skilled restoration artisans. At present, Vietnam still faces a shortage of professionals capable of working effectively in this interdisciplinary environment. Additionally, there remains a degree of hesitation among some stakeholders who fear that applying new technologies might compromise the "antique" nature of heritage sites. Public understanding of heritage conservation also varies, with many differing or limited views. Even the painstaking restoration of Notre-Dame Cathedral in Paris has sparked considerable public debate and criticism.

4. Proposed direction for Da Nang city

Following its merger with Quang Nam province, Da Nang city is set to become a cultural heritage hub of central Vietnam, as it will encompass two UNESCO recognized World Heritage Sites: the Ancient Town of Hoi An and the My Son Sanctuary, along with a system of urban heritage structures left by the French.

Given its historical and cultural significance, the city needs to research and develop an effective architectural heritage conservation strategy that combines the preservation of historical values with the application of advanced technologies. Drawing from France's experiences and lessons in applying technology to architectural heritage conservation, the authors propose the following directions:

4.1. Establishing a center for the digitization of architectural heritage

One of the first and most important steps is the establishment of a heritage digitization center, which will be responsible for collecting, storing, and managing data on the city's cultural and historical sites. The center will not only enhance heritage preservation but also foster collaboration with domestic and international partners. Through this, it enables the sharing of information and experience, attracts financial resources, and promotes international cooperation.

Table 1. *Proposed three-phase plan for establishing the Heritage digitization center in Da Nang*

Phase	Main Activities	Duration & Implementing Units	Notes
1. Initiation (Year 1)	- Conduct pre-feasibility study - Submit project proposal for approval by the City People's Committee - Select site for the center	6 months Department of Construction, Department of Culture & Sports, DUT-UD	Existing facilities may be utilized
2. Establishment (Year 2)	- Recruit personnel (architects, civil engineers, technology experts, historians, archaeologists) - Purchase equipment (3D scanners, high-performance computers, BIM software, etc.) - Develop database and center website	1 year Newly established center in collaboration with the Department of Construction, Planning Institute, universities	Technical support may be requested from France
3. Operation (From Year 3 onward)	- Digitize key heritage sites - Create H-BIM records for each site - Collaborate with departments to develop conservation plans based on collected data	First 3 years: 30 sites 10–15 additional sites per year Center in coordination with Department of Construction, Faculty of Architecture (DUT-UD), French experts	Data should be made publicly accessible at appropriate levels

4.2. Digitizing all valuable architectural structures for archival, assessment, and classification purposes

Currently, the city has developed the Da Nang heritage digital map application, but it remains limited to listing monuments and sharing historical information and photographs. It is necessary to expand efforts to collect current condition data, create 3D reconstructions, identify issues such as cracks and deterioration, and implement H-BIM technology. Given the feasibility of this work, it would not only help preserve information about heritage sites but also create an accessible and actionable data platform.

Once digitized, the architectural heritage records will include the most complete and accurate technical data, serving as a basis for heritage classification. This will support authorities in assessing the significance and vulnerability of each site and allow for the development of appropriate conservation measures.

4.3. International cooperation with France to train and enhance the expertise of conservation professionals

France, with its long-standing tradition and experience in heritage conservation, is an ideal partner for training human resources for the city of Da Nang. In addition, the legacy of French-built urban architectural heritage has contributed significantly to shaping the city's distinctive character, with many of these structures now serving as museums and key administrative buildings.

Moreover, France holds a vast archive of documents and architectural drawings related to the origins of colonial heritage systems, as well as records and inventories concerning the cultural heritage of the Champa

civilization. Strengthening connections and cooperation with French organizations, research institutes, and conservation experts would support Da Nang in developing a qualified professional team capable of applying advanced technologies in conservation work. International collaboration with France is a key step for Da Nang to improve the quality of its heritage preservation efforts.

4.4. Training human resources for heritage conservation

As one of the leading architecture schools in the Central and Central Highlands region, the Faculty of Architecture at the University of Danang's University of Science and Technology is well equipped to train high quality human resources capable of taking on significant roles in heritage conservation.

The current curriculum of the faculty not only provides courses in architectural history and heritage, helping students understand the cultural values of heritage, but also equips them with practical skills through field trips both domestically and abroad, sketching and measuring existing conditions, and proposing conservation solutions for heritage sites.

At the same time, the Faculty of Architecture is actively implementing the use of software technologies such as Autodesk Revit and 3D SketchUp in design and implementation. This enables students to master these technologies and gain practical skills relevant to their field of study and professional work after graduation.

Figure 10. *In May 2025, the University of Science and Technology collaborated with the Da Nang Department of Construction to promote innovation and digital transformation. Using the current computer lab in zone "Smart building", the Faculty of Architecture has been training second-year students in technical drawing and graphic software. (source: DUT-UD, 2025)*

This helps equip students with the necessary tools to become architects and conservation experts, providing them with the competence, knowledge, and skills needed to participate in the preservation and promotion of architectural heritage, contributing to the protection and development of important heritage sites in the country.

5. Conclusion

The application of advanced technology in heritage preservation in France has shown significant results, not only in restoring and protecting historical structures but also in enhancing the tourism experience and promoting sustainable economic development. From these experiences, Vietnam, especially Da Nang, has the potential to adopt, implement, and master similar technologies to preserve heritage more effectively and foster cultural tourism in a modern and sustainable direction.

As the cultural heritage center of the Central region after its merger with Quang Nam province, Da Nang needs to establish a comprehensive architectural heritage preservation strategy that combines historical value conservation with the application of modern technology. The establishment of a digitalization center, the implementation of 3D restoration technology and H-BIM for heritage storage and evaluation, promoting international cooperation with France, and providing high-quality local human resource training are feasible and essential directions. These solutions will not only contribute to the effective preservation of the city's rich urban heritage system but also lay the foundation for sustainable development in culture, education, and tourism in the future.

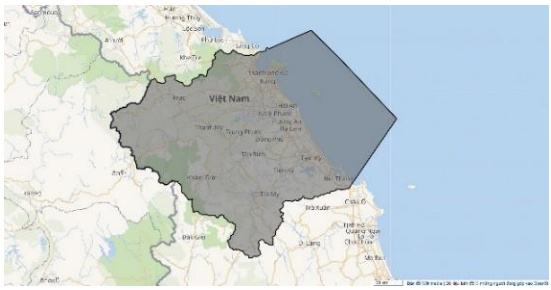

Figure 11. *Administrative boundaries of Da Nang city as of now (source: Wikimedia map, June 2025)*

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