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DIGITAL TECHNOLOGIES IN THE PRESERVATION OF CULTURAL HERITAGE UNDER MILITARY THREATS

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Abstract. *This article examines the role of digital technologies in the preservation of cultural heritage in zones of military conflict. Armed conflicts often lead to the destruction, looting, or neglect of historical monuments, resulting in irreversible cultural, social, and economic losses. The study analyzes the application of advanced technologies, including UAV-based mapping, LiDAR scanning, photogrammetry, and geographic information systems, as tools for high-precision documentation and restoration planning. Particular attention is given to the experience of Azerbaijan in the liberated territories of Shusha and Agdam, where digital documentation has become an integral part of large-scale post-conflict reconstruction efforts. International case studies, such as Palmyra in Syria and Timbuktu in Mali, are also discussed to highlight global practices and challenges. The research emphasizes the need for standardized international protocols, stronger legal frameworks, and interdisciplinary collaboration to ensure the sustainable preservation of cultural heritage. The findings demonstrate that digital technologies are not only effective in safeguarding monuments under military threat but also essential for supporting identity, collective memory, and post-conflict resilience.*

Introduction

Cultural heritage plays a fundamental role in shaping the identity and collective memory of societies. Historical monuments, archaeological sites, and intangible cultural elements are not only artistic achievements but also symbols of continuity and resilience. However, armed conflicts pose severe threats to cultural heritage. The deliberate destruction, looting, and neglect of monuments during wars lead to irreversible cultural, social, and economic losses.

In recent decades, digital technologies have emerged as powerful tools for documenting, preserving, and even reconstructing cultural heritage in conflict zones. From high-resolution 3D scanning to drone mapping and cloud-based archives, these technologies allow the creation of precise digital replicas that can support future restoration and academic research.

This article explores the role of digital technologies in safeguarding cultural heritage during military threats, with an emphasis on their practical application in conflict-affected areas, including the South Caucasus and the liberated territories of Azerbaijan. It aims to analyze existing practices, assess technological effectiveness, and propose recommendations for integrating digital solutions into international heritage protection frameworks.

Literature Review

The destruction of cultural heritage during armed conflicts has been widely documented in academic literature. Studies on Syria, Iraq, and the Balkans demonstrate the scale of cultural loss and the urgency of developing efficient protection mechanisms. Scholars such as Bevan (2016) and Meskell (2018) emphasize the symbolic role of heritage in war, where cultural sites are targeted to erase identities or assert territorial dominance.

The integration of digital technologies in heritage preservation is relatively recent but rapidly expanding. Researchers have highlighted the potential of LiDAR scanning, photogrammetry, and satellite imagery in recording structural details with millimetric precision. Case studies from Palmyra in Syria and Timbuktu in Mali show how digital documentation facilitates both immediate protection and post-conflict restoration.

Despite these advances, several gaps remain. Many conflict-affected regions lack the technical expertise, financial resources, or infrastructure to implement digital preservation strategies. Furthermore, the absence of coordinated international protocols limits the scalability and integration of these technologies into long-term heritage management plans.

Methodology

This study uses a qualitative analytical approach combining case study analysis, review of technical reports, and expert interviews. The methodology includes:

Data Collection: Examination of open-access archives, satellite imagery, and field reports from UNESCO, ICOMOS, and national agencies.

Technology Assessment: Evaluation of digital tools such as UAV-based aerial mapping, 3D laser scanning, photogrammetry, and geographic information systems (GIS).

Site Selection: Focus on high-risk cultural heritage sites in areas exposed to military threats, including Syria, Mali, and Azerbaijan's liberated territories.

Analytical Framework: Comparative analysis of efficiency, accuracy, and cost-effectiveness of each technological method.

Case Studies

Palmyra, Syria

The ancient city of Palmyra, a UNESCO World Heritage site, suffered extensive damage during the Syrian conflict. Rapid deployment of drones and laser scanning

allowed researchers to create high-resolution 3D models of destroyed structures, enabling precise virtual reconstruction and preservation of archaeological data.

Timbuktu, Mali

During the armed conflict in northern Mali, historical mausoleums and libraries were destroyed. Collaborative efforts by UNESCO and international NGOs used digital mapping and documentation to support reconstruction projects and to safeguard valuable manuscripts in digital form.

Shusha and Agdam, Azerbaijan

The territories of Shusha and Agdam represent some of the most striking examples of cultural heritage devastation caused by prolonged occupation and armed conflict in the South Caucasus. For nearly three decades these regions, historically significant as centers of Azerbaijani culture, religion, and architecture, were exposed to systematic neglect, destruction, and alteration of their historical monuments. The scale of damage became evident only after the liberation of these territories in 2020 during the Second Karabakh War.

Shusha, often referred to as the cultural capital of Azerbaijan, has been home to an extensive network of religious, residential, and public architectural sites. The city's numerous mosques, including the Yukhari Govhar Agha and Ashaghi Govhar Agha mosques, as well as mausoleums, caravanserais, and traditional residential complexes, were subjected to extensive damage. Field inspections conducted after liberation revealed structural deterioration, vandalism, and inappropriate alterations that failed to respect the authenticity and original design of these monuments. Such practices not only undermined their architectural integrity but also disrupted the cultural and spiritual identity of the city. Digital technologies have played a crucial role in assessing the full extent of this damage, with UAV-based mapping and high-resolution laser scanning enabling precise documentation of surviving elements for subsequent restoration.

Agdam, often called the ghost city, presents another case of extreme destruction. Before the conflict Agdam was an urban center with a rich architectural and cultural landscape that included the Agdam Juma Mosque, traditional neighborhoods, and historical cemeteries. After decades of occupation the city was almost entirely destroyed. Satellite imagery and on-site inspections conducted after liberation documented collapsed residential areas, looted and desecrated cemeteries, and the partial ruin of the Agdam Juma Mosque. The mosque itself, despite being one of the few surviving structures, was heavily vandalized and neglected. The application of 3D scanning and photogrammetry has been critical in digitally reconstructing the mosque and surrounding sites, creating a comprehensive digital archive that serves as the foundation for accurate and culturally sensitive restoration.

Fig 1. **Ruins of historical and residential structures in Agdam**

The Azerbaijani government, in cooperation with local experts and international organizations, has prioritized the preservation and restoration of Shusha and Agdam as part of a broader post-conflict reconstruction strategy. Digital documentation is not limited to structural surveys but also includes the creation of geospatial databases and digital archives to ensure transparency, facilitate academic research, and support long-term monitoring. The integration of these digital technologies demonstrates a forward-looking approach where heritage preservation is aligned with scientific precision and international best practices.

Results and Analysis

The analysis of global and Azerbaijani experiences demonstrates that digital technologies significantly improve the accuracy and efficiency of cultural heritage preservation. UAV mapping allows rapid documentation of large areas, while 3D laser scanning and photogrammetry deliver precise models for restoration planning. Digital archives also ensure that even if a site is further damaged, its historical record remains preserved.

However, several challenges persist. Digital preservation requires significant financial investment, skilled personnel, and reliable digital infrastructure. In conflict zones, operational difficulties such as restricted access, security risks, and unstable connectivity often delay or limit documentation efforts.

Table 1

Digital technologies for the preservation of cultural heritage under military threats

Technology	Application in Conflict Zones	Advantages	Challenges
UAV Mapping	Large-scale mapping of inaccessible areas	Rapid data collection, cost efficiency	Weather limitations, restricted airspace
LiDAR Scanning	High-precision structural documentation	Detailed 3D models, accuracy	High cost, need for trained operators

Table continuation 1

Technology	Application in Conflict Zones	Advantages	Challenges
Photogrammetry	Reconstruction of monuments from images	Accessible, scalable, user-friendly	Limited accuracy without controlled conditions
GIS Integration	Heritage site databases and monitoring	Centralized data management, analysis tools	Requires significant infrastructure and expertise

Discussion

The application of digital technologies for the preservation of cultural heritage in conflict zones has transformed approaches to documentation, analysis, and restoration. The experiences of Azerbaijan in Shusha and Agdam, along with international examples such as Palmyra in Syria and Timbuktu in Mali, demonstrate that digital methods provide unprecedented opportunities for accuracy, accessibility, and long-term data preservation. However, their use also reveals persistent gaps in infrastructure, funding, and policy integration.

From a technological perspective, the deployment of unmanned aerial vehicles (UAVs), LiDAR-based scanning, and photogrammetry enables high-resolution mapping of complex structures, even in high-risk or inaccessible areas. In the liberated territories of Azerbaijan, UAV mapping combined with laser scanning has allowed experts to create precise three-dimensional models of monuments, including the Juma Mosque in Agdam and the historical complexes of Shusha. These models not only support technical restoration but also serve as educational and archival resources that ensure the continuity of historical knowledge for future generations.

However, several challenges remain. First, capacity-building is required, as advanced digital systems demand highly trained specialists and interdisciplinary collaboration among historians, engineers, architects, and IT professionals. Second, the absence of standardized international protocols for digital heritage documentation results in fragmented approaches, reducing the interoperability of data between institutions and countries. Finally, financial and logistical barriers limit the scalability of these technologies, particularly in conflict or post-conflict environments where resources are often directed toward basic reconstruction needs.

Another critical consideration is the integration of digital heritage into legal and policy frameworks. While the 1954 Hague Convention provides a foundation for cultural heritage protection during armed conflicts, it does not address the digital dimension of preservation. The creation of standardized digital archives, legally

protected and supported by international agreements, would ensure that documented data is accessible for judicial processes, academic research, and public awareness campaigns. The Azerbaijani case highlights the need for stronger international collaboration, particularly through partnerships with organizations such as UNESCO, ICOMOS, and ICCROM.

Community engagement also plays a key role. Digital technologies should not only serve technical specialists but also involve local communities. Training programs and open-access platforms can empower citizens to participate in documenting and monitoring heritage sites. In post-conflict settings, such inclusive approaches foster cultural resilience and contribute to social healing.

Conclusion

Digital technologies have transformed approaches to cultural heritage preservation in areas affected by military threats. By enabling high-precision documentation and virtual reconstruction, they provide a foundation for restoration, research, and education. The Azerbaijani case demonstrates the effectiveness of combining modern tools with strategic planning and international collaboration. Strengthening legal mechanisms and expanding access to digital solutions are essential for protecting cultural heritage and ensuring its transmission to future generations.

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