Advanced 3D Documentation and Capacity Building for Post-Conflict Damage Assessment: The Case of the Taras Shevchenko Chernihiv Regional Academic Music and Drama Theatre, Ukraine

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Abstract

This paper presents the methodologies and findings from of a technical mission undertaken to document and assess the Taras Shevchenko Chernihiv Regional Academic Music and Drama Theatre in Chernihiv, Ukraine — an emblematic cultural landmark within the Historic Centre of Chernihiv, which is included on Ukraine’s Tentative List and sustained significant damage in August 2023. Conducted through a UNESCO/ICOMOS partnership, the mission combined advanced architectural documentation techniques with capacity-building activities for local professionals and students. Emphasizing the use of terrestrial laser scanning, photogrammetry, and sophisticated geospatial analysis, this document details the methodological approach taken, the structure of the training programs implemented, the obstacles encountered during the mission, and the resulting deliverables. This study serves as a valuable reference for employing integrated strategies in post-disaster interventions for cultural heritage sites.

1. Cultural Heritage, Disasters and the Role of Documentation

Cultural heritage is increasingly threatened by both natural and man-made disasters. Earthquakes, floods, and armed conflict frequently damage or destroy monuments, historic buildings, and intangible practices tied to community identity. The loss is not only architectural but deeply cultural, affecting a society's sense of continuity and belonging (Ünal, 2015). International frameworks such as the Sendai Framework for Disaster Risk Reduction (2015–2030) emphasize cultural heritage as a vital dimension of disaster resilience. ICCROM’s Cultural Heritage First Aid (CHFA) training and the UNESCO Rapid Response Mechanism have institutionalized rapid deployment strategies and training to protect at-risk heritage globally (ICCROM, 2023). Risk management planning should integrate inventory building, local governance, community training, and multi-level response systems (Yıldırım-Esen et al., 2019).

In this context, accurate 3D documentation becomes a crucial first step for understanding, evaluating, and restoring damaged heritage structures. It also supports evidence-based recovery and legal protection mechanisms post-conflict. Documentation serves not only a post-disaster assessment function but also contributes significantly to preparedness and mitigation. High-resolution 3D documentation allows for the archiving of accurate geometries, conditions, and materials prior to potential damage. It forms the basis for Building Information Modelling (BIM), structural analysis, and virtual reconstruction (Stylianidis & Remondino, 2016). Furthermore, it supports legal claims and insurance procedures in conflict or disaster-related loss scenarios.

2. The T.G. Shevchenko Theatre

The T.G. Shevchenko Theatre, located in Chernihiv, whose historic centre has been Ukraine’s Tentative List since, has been in existence for almost 100 years. It was founded in Yelisavetgrad in 1926 and named after Taras Shevchenko. In 1933, the theatre was moved to the Chernihiv region, where it still exists to this day. The construction of the theatre began in 1953. In 1955 and 1956, there was a shortage of wood, cement, and metal, and concrete for laying curbs was delivered untimely, but the theatre was still successfully completed. The building for the Chernihiv Drama Theater was opened in 1959. It is executed in a classical style and resembles an ancient Greek temple. The facade of the theatre building is decorated in the form of a portico with eight columns. The pediment is adorned with a relief composition in the centre of which is the kobzar Taras Shevchenko, and on both sides of him are the heroes of his works. The theatre is three stories high, located between Krasna Square and Bohdan Khmelnytsky Square. With its construction, the ensemble of the central part of Chernihiv was completed, and since then, the theatre has served as a central venue for performing arts, cultural events, and civic life in Chernihiv. On 19 August 2023, the building sustained severe damage from a missile strike, resulting in significant structural compromise to the roof and interior halls (Fig. 1). Despite these challenges, the theatre remains a powerful icon of local resilience and heritage.

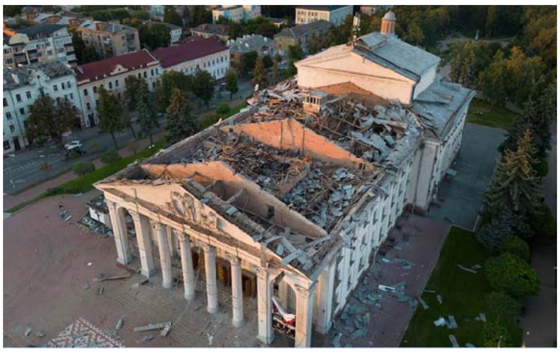

Figure 1. Aerial photo of the effects of the attack in the Theatre. (https://time.news/missile-attack-on-chernihiv- theater-updates-and-global-impact-august-2023/)

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3. The Mission

The field mission to the Taras Shevchenko Chernihiv Regional Academic Music and Drama Theatre in Chernihiv was carried out as part of a broader post-conflict emergency response framework coordinated by UNESCO in partnership with ICOMOS, namely the framework of the UNESCO/Japan Funds-in-Trust Project 'Support for Ukraine in culture and education through UNESCO; Emergency response for World Heritage and cultural property: damage assessment and protection, and in close consultation with the Ministry of Culture and Strategic Commmunications of Ukraine (MCSC) The mission had a dual scope: first, to conduct advanced documentation for conservation and damage assessment of the site; and second, to deliver on-site training and capacity building for Ukrainian specialists, including members of the Working Group established by the Ministry for developing a rehabilitation plan for the Historic Centre of Chernihiv. This operation formed part of a progressive engagement that included a prior UNESCO/ICCROM damage assessment mission in October 2023, followed by a series of four online technical workshops hosted by UNESCO and ICOMOS (December 2023 to April 2024), and a first UNESCO/ICOMOS in-person mission in March 2024. These efforts were designed to provide a methodological framework and guidance for the preparation of comprehensive guidelines for the development of a rehabilitation plan of the Historic Centre of Chernihiv, including recommendations on emergency preparedness for priority cultural heritage sites damaged during the war.

The field mission to Chernihiv, executed between 29 April and 3 May 2024, was a practical continuation of this framework, targeting the emblematic Shevchenko Theatre due to both the severity of the damage and its cultural significance. The mission’s primary technical objective was the production of detailed architectural documentation capturing the current state of conservation and structural integrity of the theatre. Despite the ambition of the original scope, several adjustments were made due to constraints imposed by the ongoing conflict. Drone surveys were prohibited for safety and regulatory reasons, resulting in the omission of aerial coverage. Likewise, photogrammetry was restricted to interior areas with safe access and adequate lighting. Consequently, terrestrial laser scanning became the mission’s primary data acquisition tool for geometric documentation. In parallel with the technical documentation, the mission implemented a structured training program aimed at transferring knowledge and technical skills to local heritage professionals and university students. Participants included designated members of the Ministry’s Working Group and students from Chernihiv Polytechnic National University. The pedagogical approach combined theoretical lectures, translated written tutorials, and guided fieldwork exercises (Fig. 2a & b). Hands-on experience with hardware and software tools enabled participants to take an active role in all stages of the mission, from data acquisition to preliminary processing.

This dual-track mission—pairing emergency documentation with capacity building—demonstrates the viability and necessity of knowledge transfer in conflict-affected heritage contexts. It ensures that the technical legacy of the mission is not only a dataset, but also a trained local network capable of continuing documentation and conservation efforts autonomously.

Figure 2. Fieldwork demonstrations (a) & (b). (©)UNESCO

4. Methodology

4.1 Documentation Approach

The architectural documentation strategy was designed with careful consideration for the site's post-conflict condition, time constraints, and the absence of aerial access. The methodology followed principles outlined in the Geospatial Survey Specifications for Cultural Heritage by Historic England, emphasizing precision, repeatability, and multi-sensor integration. This multi-modal approach ensured a rich, layered dataset capable of supporting condition assessment, rehabilitation planning, and future conservation. Documentation targeted the theatre’s façades, interiors, roof structure, and severely damaged areas like the atrium and main stage. All deliverables were to be referenced in a unified coordinate system and conform to a scale-appropriate graphical output (1:50–1:200).

4.2 Surveying and Control Network

Establishing a robust geospatial control network was critical for aligning all captured datasets within a shared and precise reference system. A hybrid methodology was employed, utilizing GNSS receivers (Emlid RS+, L1 signal) alongside a Leica TS02 Total Station to develop a trigonometric traverse across the site.

The key components of the control network comprised:

- Seven GNSS-measured points, which were referenced to the WGS 84 / UTM zone 37N + EGM2008 coordinate system to facilitate accurate georeferencing.

- Traverse measurements that linked Ground Control Points (GCPs), laser scanner targets, and auxiliary points, thereby enhancing spatial referencing accuracy.

- Triangulation adjustments that utilized standard deviation and precision calculations to ensure sub-centimeter accuracy across all deliverables.

This network ensured that point cloud data, orthomosaics, and derived vector drawings maintained spatial coherence. Coordinate data and precision values were systematically organized in tabulated format and embedded within the final archive, accompanied by comprehensive metadata.

4.3 3D Terrestrial Laser Scanning

To accurately capture the architectural geometry of the theatre, a dual Terrestrial Laser Scanning (TLS) approach was employed utilizing two complementary systems. The Z+F Imager 5010X was used for long-range exterior scans and detailed interior captures, focusing on central staircases, corridors, and entrance areas. It achieved a resolution of 6 mm at distances between 10 and 15 meters, with sub-millimeter precision. Specific scans incorporated HDR color imaging to address documentation needs related to material and surface analysis. The Leica BLK360 Gen 1 was deployed for mid-range scanning of secondary interior spaces and areas that were challenging to access. Due to time constraints, color capture was limited to strategically important decorated spaces.

In total, 836 TLS scans were collected throughout multiple floors, with HDR imagery selectively applied to enhance visual analysis in critical areas (Fig. 3). For registration and data integration, LaserControl 9.3 was used to process the Z+F datasets by performing target-based and cloud-to-cloud alignment, achieving a registration deviation of 2–4 mm across the cloud data. Cyclone Register 360 Plus handled the BLK360 datasets, organizing scans by floor while integrating Z+F datasets as reference points for precise connection and alignment. The final registration was confirmed against the control network established through the total station targets (Fig. 4).

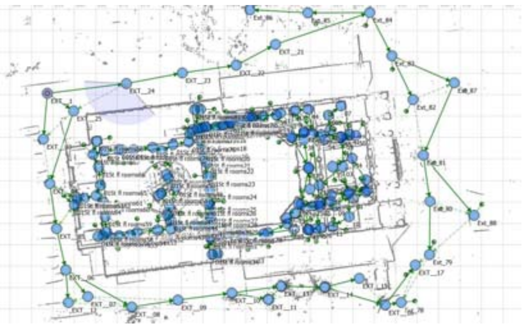

Figure 3. Bundle network and overview of the scan positions. (©UNESCO/ICOMOS)

Figure 4. Overview of the combined point clouds produced by the laser scanning process. (©UNESCO/ICOMOS)

Some challenges emerged, particularly on the southern side of Floor 1, where gaps in data resulted in a disconnected bundle. This area required additional scans for complete integration that were performed later within the same year (June & October 2024). The project yielded several derived products, including orthoimages of façades produced at a scale of 1:100, comprehensive 2D architectural drawings (floor plans, elevations, and cross-sections) at a scale of 1:200, a topographic map with 0.5 m contour intervals generated through point cloud surface extraction, and panoramic views derived from scanner imagery for immersive inspection of the scanned environments.

4.4 Terrestrial Photogrammetry

Photogrammetry was utilized in two significantly compromised interior spaces—the main stage and the atrium—to capture intricate surface details and produce precise orthomosaics essential for conservation planning. The image acquisition was conducted with a Canon EOS R10 outfitted with an RF 24mm f/1.8 lens and a Sony A7RIII using a TAMRON 28–75mm f/2.8 lens, specifically in low-light conditions to enhance detail. Shooting distances were maintained between 5 to 10 meters, intentionally avoiding steep angles to maximize scene coverage.

The processing involved a Structure-from-Motion (SfM) technique for camera alignment and the generation of a sparse point cloud. Following this, Multi-View Stereo (MVS) methods were employed for the reconstruction of a dense point cloud. Precision in georeferencing was achieved at sub-centimeter accuracy (≤1.2 cm) through the integration of Ground Control Points (GCPs). The outputs included high-resolution orthomosaics depicting collapsed roof sections and ornate wall surfaces, along with 3D mesh models of critical interior areas (Fig. 5).

Figure 5. The orthomosaic of the damaged atrium produced using the photogrammetric method. (©UNESCO/ICOMOS)

4.5 Record Photography

Record photography played a vital role in the comprehensive documentation of the T.G. Shevchenko Theatre. While laser scanning and photogrammetry offered high-resolution spatial and geometric data, record photography focused on capturing detailed visual information about architectural features, materials, and damage conditions that are often missed in broader survey methods.

The photography aimed to create a visual inventory of all accessible interior and exterior spaces, document architectural and decorative elements in high detail, provide conservation-grade images that support condition assessments and intervention planning, and contribute to the long-term digital archive as a benchmark for monitoring future changes.

Two high-resolution cameras were used: (i) a Canon EOS R10 with an RF 24mm f/1.8 Macro IS STM lens, and (ii) a Sony A7RIII with a TAMRON 28–75mm f/2.8 lens. Photographs were taken under varied lighting conditions using only natural or ambient light, which imposed certain exposure limitations but also reflected the authentic state of the structure. Photographs focused on close-up documentation of wall paintings, plasterwork, joinery, and surface decay, while also capturing contextual views of spaces to complement scanning data, including hard-to-scan areas such as ceilings, niches, and furnishings (Fig. 6). Each photograph was systematically referenced to physical locations using either annotated floor plans or tabular metadata with room numbers, orientation, and focal subject. This referencing ensures traceability and facilitates the integration of photographic data with the 3D models and architectural drawings. Image files were saved and accompanied by descriptive metadata including date, location, camera settings, and photographer.

Record photography supports baseline condition assessment prior to conservation treatment and change detection over time when compared against future documentation efforts. It also enhances public engagement, education, and remote inspection by stakeholders unable to access the site directly. The photographs will remain a permanent part of the project’s archive, ensuring that future interventions can rely not only on geometric precision but also on rich visual evidence of material condition and artistic details.

Figure 6. Examples of record photography (top left to bottom right: construction plans, control room on F3, detail in room 85, archives in F1, ©UNESCO/ICOMOS)

5. Capacity Building and Empowering Local Experts

Local communities play a vital role in effective disaster response. Participatory approaches ensure that documentation efforts align with community values and that recovery priorities reflect lived heritage significance (Ünal, 2015). Training programs targeting local professionals and stakeholders help establish an enduring knowledge base that can be activated during emergencies. When digital documentation is paired with local capacity building, it becomes a sustainable asset rather than a one-off technical intervention.

A parallel objective of the mission was to build local capacity in advanced documentation. Workshops were conducted with students and staff from the Chernihiv Polytechnic National University (Fig. 7). Hands-on training included GNSS positioning, Total Station use, scan setup, photogrammetry principles, and software processing. Open-source and commercial tools such as CloudCompare and Recap were demonstrated. Instructional materials were translated into Ukrainian, and modular tutorials allowed small groups to rotate through documentation tasks under expert guidance. This investment in local knowledge aims to support long-term resilience and professional independence in heritage conservation.

Figure 7. Group photo of the UNESCO/ICOMOS team, students and professors, and interpreters (©UNESCO).

The training session was designed to achieve several objectives, which include developing an understanding of the significance of recording and presenting visual information for conservation purposes, examining the strengths and limitations associated with various recording techniques, and acquiring the skills necessary to synthesize information from diverse sources into cohesive presentations.

5.1 Field Demonstrations and Equipment Familiarization

The training started with the on-site field demonstrations that were conducted in order to reinforce the connection between data acquisition and processing, emphasizing the importance of accuracy, spatial referencing, and methodological consistency in cultural heritage documentation. Students participated directly in setting up and using the available laser scanners, operating the total station, conducting GNSS measurements and control point setup and finally acquiring digital images to further process them using photogrammetric methods.

5.2 Photogrammetry Training

Photogrammetry sessions were structured around small-group instruction led by members of the CIPA/ICOMOS documentation team. Students were divided into teams, each assigned to a mentor for guided theory and fieldwork. Participants selected fallen gypsum decorative elements and wall segments from the theatre’s damaged dome area for their case studies. Using DSLR cameras or smartphones, students photographed the objects under instruction, placing and measuring targets to enable accurate model scaling. Instruction emphasized proper overlap and coverage in image capture, optimal camera distance and framing, lighting management, and practical elements of exposure control, including ISO, shutter speed, and aperture.

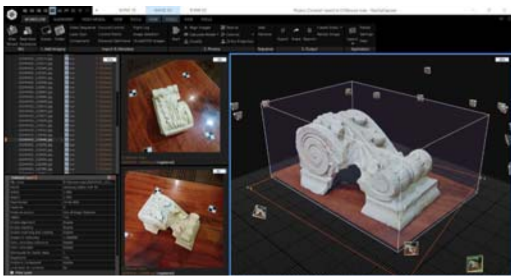

Figure 8. Screenshot of the processing in Reality Capture of one of the ornaments as an outcome of the training sessions. (©ICOMOS)

After image acquisition, the photographs were processed into 3D models using Reality Capture. Students were introduced to a simplified workflow encompassing image alignment, sparse and dense cloud generation, and mesh creation, culminating in the production of usable 3D documentation models (Fig. 8). This full-cycle approach underscored photogrammetry's versatility in capturing, preserving, and reconstructing cultural assets.

5.3 Point Cloud Processing and CAD Integration

A critical part of the training was equipping students with practical skills in the processing and interpretation of point cloud data to generate architectural deliverables. The session emphasized the transition from raw 3D scans to usable technical drawings, as well as the exploration of both commercial and open-source tools suitable for heritage documentation projects.

Emphasis was placed on educating the participants regarding the comprehensive digital workflow encompassing terrestrial laser scanning and architectural representation. An in-depth lecture covered the core stages of this process, starting with the registration of scan data, while after students learned how to clean and prepare point clouds in Autodesk Recap and then import and align the scan data in CAD software using User Coordinate Systems (UCS). They generated 2D outputs, including plans, sections, and elevations, directly from point cloud data.

To assist participants with limited experience in traditional CAD environments, PointCab Origins was introduced as a simplified alternative for point cloud slicing and vector extraction. The software's intuitive interface and efficient workflows allowed for rapid generation of orthographic views and floor plan bases. Instruction was delivered through live demonstrations projected in real time, enabling participants to observe data as it progressed through each software environment. Coupled with bilingual tutorials provided beforehand, the session effectively bridged theoretical knowledge with applied technical workflows.

In addition, participants were introduced to CloudCompare, an open-source software solution for 3D data management, which further supported sustainable and accessible documentation practices. The training emphasized CloudCompare's capabilities, including cleaning, editing, and segmenting large point clouds, generating contour lines, creating orthographic projections and mesh surfaces, animating 3D data for presentations or assessments, and integrating workflows with other CAD/BIM environments. The software's no-cost availability and robust feature set were highlighted for professionals and institutions with limited access to proprietary software. By exposing participants to both premium and free tools, the training aimed to democratize access to digital documentation technology and ensure methodological flexibility for future projects.

6. Results, Challenges and Lessons Learned

The mission to document the T.G. Shevchenko Theatre produced a wide array of deliverables aligned with international documentation standards. These outputs were made possible through the integration of terrestrial laser scanning, photogrammetry, CAD workflows, and high-resolution record photography. A comprehensive set of 33 architectural drawings and orthoimages was created, featuring topographic site plans, ortho-projected elevations, detailed floor plans, and decorative elements captured through photogrammetry (Fig. 9 & 10).

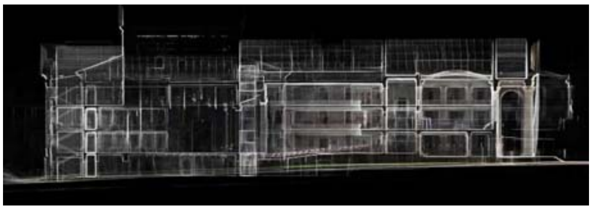

Figure 9: Screenshot of the longitudinal section of the theatre in OpenScanTools (©UNESCO/ICOMOS)

The workflows utilized 3D laser point clouds processed with various software tools. Additionally, 360° panoramic views were generated from Z+F and Leica scans, allowing virtual navigation of the site. These panoramas include both colour and black and white formats and can be explored using software like FSPViewer or THETA 360. A photographic inventory was also compiled, focusing on significant architectural details in each accessible room, ensuring a balanced visual record alongside the panoramic imagery.

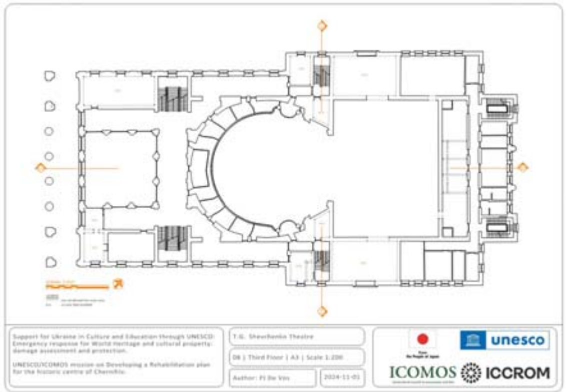

Figure 10: Deliverable: Drawing 08 – Plan of 3rd floor – Scale 1:200

The mission successfully achieved its documentation goals but faced several challenges. Time constraints hindered thorough documentation, as 30% of the mission was devoted to training, often disrupted by air raid alerts. The theatre's ongoing operations restricted access to key areas, complicating logistical arrangements and data collection. Additionally, construction work made roof access impossible during the first phase, requiring follow-up visits for scanning. Operating in a conflict zone introduced unpredictability, with daily air raid alarms interrupting activities, though training continued in shelters. Equipment limitations included missing survey tools and lens kits for cameras, which impacted documentation quality. Drone use was restricted, suggesting a need for alternative imaging solutions in future missions.

The mission yielded valuable insights that can guide future heritage documentation projects, particularly in post-disaster or active-conflict contexts. Early coordination between training and documentation components is essential to optimize time and resource allocation. A detailed pre-mission equipment checklist should include redundancy planning and versatile accessories tailored to site-specific conditions. Flexible documentation strategies, including the use of lightweight and open-source software, ensure mission continuity even under restrictive conditions. Local capacity building, combined with the adaptability of both trainers and trainees, proved fundamental to mission success—even under frequent disruptions. Finally, a phased documentation plan—allowing for return visits when access is limited—can help ensure comprehensive and high-quality outcomes, even in constrained environments.

7. Conclusion

The field campaign at the Taras Shevchenko Chernihiv Regional Academic Music and Drama Theatre in Chernihiv, Ukraine, represented an important contribution to the broader effort to document and support cultural heritage preservation in conflict-affected areas. The mission was conceived with a dual purpose: to document the theatre’s current conservation status using advanced technologies, and to provide comprehensive, hands-on training to local students and professionals in the field of heritage documentation.

Despite operating under challenging conditions, the campaign succeeded in generating a robust dataset and delivering meaningful capacity building and allowing for the production of highly accurate 2D and 3D outputs. These products offer a foundational resource for future restoration and conservation planning and contribute to the broader goals of emergency preparedness and post-conflict recovery. Equally important was the training component, which empowered participants with both theoretical knowledge and practical skills. Through this collaborative and immersive approach, the mission helped establish a local foundation for sustained heritage documentation work in Ukraine.

Ultimately, the campaign reflects the vital role that international cooperation plays in cultural heritage protection. By uniting the technical expertise of international partners with the dedication of local actors, this project not only preserved valuable architectural knowledge but also fostered resilience and preparedness within the community. The documentation and capacity-building outcomes from this mission will serve as a lasting asset in the stewardship of the T.G. Shevchenko Theatre and as a model for similar efforts in conflict-affected regions worldwide.

Acknowledgements

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