Participatory Heritage Documentation: Low-cost Photogrammetry of Decayed Historic Buildings in the Medina of Tunis

Mara Cruz [1], Alejandra Albuerne [2,3]

[1] Institute for Sustainable Heritage, University College London, Upper Woburn Place, London, WC1H 0NN – mara.cruz@ucl.ac.uk
[2] IE School of Architecture and Design, IE University, Madrid, Spain – alejandra.albuerne@ie.edu
[3] Bartlett School of Architecture, University College London, Gordon Street, WC1H 0QB

Keywords: Low-cost photogrammetry, Built Heritage documentation, Capacity building, Remote training, Condition Assessment, Medina of Tunis.

Abstract

This paper presents a low-cost, community-led documentation approach for endangered historic buildings in the Medina of Tunis, a UNESCO World Heritage Site facing significant conservation challenges. Focusing on Fondok El Henna—an abandoned caravanserai in a state of advanced decay—the study explores how image-based photogrammetry can be employed in resource-limited contexts through collaboration between local civil society and academic partners. Using available photographic equipment and remote training, the project successfully documented the building's façade and assessed its condition. The process relied on a modular workflow that combined field data collection by a locally trained team with remote data processing by heritage experts. Despite limited access to technical infrastructure and computing resources, the method proved effective in producing accurate 3D models and identifying key agents of deterioration, including water ingress, biological growth, and human-induced damage. The scientific contribution of this work lies in demonstrating that affordable photogrammetry can be adapted for fragile urban environments, supporting both heritage conservation and community empowerment. The paper offers a replicable methodology that lowers technical barriers and enhances local capacity, while also highlighting the roles digital documentation can play in advocacy, conservation planning, and memory preservation. This approach provides a meaningful, scalable model for documenting neglected heritage in similar contexts globally, particularly where conventional resources and institutional support are limited.

1. Introduction

Documentation is a crucial means of interpreting, understanding and conserving cultural heritage (ICOMOS, 1996). While there is a plethora of new technologies that assist in the documentation of built heritage, most of these technologies require an investment in hardware and software, as well as training, that are not accessible in all contexts. Within such contexts, it is necessary to develop low-cost digitization strategies that enable local communities to take control of the process. Image-based documentation has been proposed as a low-cost path to recording heritage assets (Mezzino et al., 2017). The transfer of the technology to communities is not, however, evident and depends on capacity building and access to the necessary computing assets.

This paper presents a civil society-led initiative to document endangered heritage buildings in the Medina of Tunis World Heritage Site (Tunisia) as an essential step in the process of exploring revitalization potential. The work takes Fondok El Henna (Fig. 1), an old *caravanserai* in an advanced state of decay, as a pilot case study for developing a replicable methodological approach. The collaborative documentation and monitoring strategy is supported on the active involvement and upskilling of the local community. Terrestrial photogrammetry is used to record the building fabric and assess its state of conservation through *remote* collaboration between a local team that engages the community, led by local heritage organisation Blue Fish, and a remote team with training and processing capacity, led by University College London (UCL). The needs for documentation, the recording process and impact achieved are highly context-dependent and are conditioned by resource availability within the Medina of Tunis.

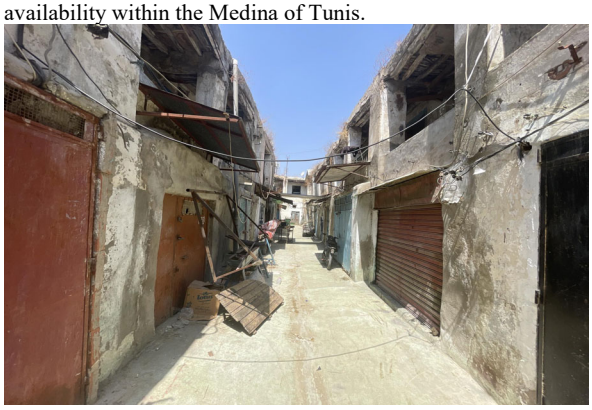

Figure 1. View of Fondok El Henna. © Amine Hamouda.

1.1 Case study: Neglected Heritage Buildings in the Medina of Tunis

The Medina of Tunis, a historic urban area inscribed as a World Heritage Site, experienced significant decline due to socio-economic changes in the mid-20th century (McGuinness, 1997). At the time of its inscription in 1979, at least 50% of its heritage was either in ruins or in a poor state of conservation (UNESCO, n.d.). Although this deterioration has led to the creation of reconstruction and planning entities, as well as various projects

over the past 40 years (McGuinness, 1997), the site still faces considerable conservation challenges. Resources for conserving and managing the Medina are tight (Chmour, 2021) and new participative models and low-cost strategies are sought that can add to the paths for preserving the World Heritage Site.

One of the challenges in conserving the Medina of Tunis is the presence of numerous derelict historic buildings, known as *kherba*. A recent survey conducted under the INNOMED-UP project identified 125 such structures within the World Heritage Site, with nearly one-third under municipal ownership. Although often perceived as abandoned, many *kherbas* are informally inhabited or used for commercial purposes. They share a common condition of severe disrepair and institutional neglect, posing risks of structural collapse and public health hazards as some have turned into waste dumps.

Despite their detrimental impact on the urban fabric, *kherbas* are viewed by many as sites of potential. Local stakeholders see them as opportunities for revitalization that align with heritage-led and people-centred urban regeneration. In the resource-constrained context of the Medina of Tunis, realizing this potential demands complex multi-disciplinary and multi-stakeholder collaboration to explore possibilities and evaluate potentials.

The documentation initiative presented in this paper is an integral part of the framework of research project 'Activating Abandoned Heritage: The Medina of Tunis' potentials and pathways' (ACTIVAH), derived from the collaboration between Tunisian civil society stakeholders, led by Tunisian social enterprise Blue Fish, and researchers from University College London (UCL, UK). ACTIVAH recognised the potential of *kherba* as activators of the Medina of Tunis and aimed to develop a replicable framework for the revitalization of neglected buildings within context with restricted access to financial and technical resources.

In such contexts, heritage documentation functions not only as a means for understanding cultural significance, but also as a critical entry point for community engagement and local capacity-building, both of which are essential to achieving sustainable conservation outcomes (Mezzino et al., 2017; Reina et al., 2021). This approach serves to empower local communities and foster a deeper connection between people and place, thereby enhancing the long-term effectiveness of conservation efforts. Research from Nepal (Dhonju et al., 2017), Morocco (Khalloufi et al., 2020), and Lebanon (Mohareb et al., 2023) have demonstrated that affordable, image-based photogrammetry can enable heritage documentation in fragile environments, particularly where high-end technologies, such as terrestrial laser scanning (TLS), and sustained on-site expertise are unavailable or inaccessible.

The present work delves further into the complexities of operating in resource-constrained environments, examining the potential of applying, and generating impact from, affordable photogrammetry by entrepreneurial civil society and community stakeholders, without direct support from local or national authorities. Following a review of the literature on low-cost photogrammetry in the context of built heritage and its potential for participation and capacity building, this paper presents an affordable documentation case study, with a focus on the workflow and remote training process developed. It then discusses the analysis and findings, exploring the constraints encountered in deploying terrestrial photogrammetry with economic and technological constraints.

2. Literature Review

2.1 Photogrammetry under Resource-Limited Conditions

Terrestrial photogrammetry is widely regarded as a "low-cost" documentation method due to its relative affordability compared to established techniques such as TLS (Murtiyoso et al., 2019; Balado et al., 2025). However, the effective application of photogrammetry does not come free and a certain level of financial and technical investment is required. There is a gap in the literature in discussing the implications posed by these costs when applying photogrammetry in resource-limited contexts for documenting large objects and sites, such as historic architecture. Experience in Tunis has identified financial and technical constraints to be real handicaps for deploying the use of photogrammetry for heritage building documentation.

The principal cost advantage of terrestrial photogrammetry lies in the data acquisition phase, which is carried out using digital cameras, readily available in most contexts. DSLR cameras equipped with high-sensitivity sensors are commonly employed. The potential of consumer-grade cameras, including those integrated into mobile phones, has also been explored with promising results (Elkhrachy 2020; Khalloufi et al. 2020). This means data collection is democratized in most contexts, including low-income and fragile environments.

However, while data capture is relatively accessible, the subsequent stages of data processing and model generation rely on further associated costs that entail more significant barriers. Computers with substantial processing power and graphics capabilities are necessary for generating 3D point clouds and meshes, and for manipulating these to generate knowledge. In many contexts, such hardware is financially prohibitive for individuals and is frequently unavailable within educational or institutional settings.

Software has conventionally represented another cost consideration. Although there exist some well-established open-source codes and free software, such as Meshroom, COLMAP or MicMac, capable of producing high-accuracy geometric models (Verykokou et at., 2021; Ortiz Sanz et al., 2021), their use presents certain limitations. In terms of operability, open-source codes often demand advanced technical skills. On the one hand, user interfaces can be less accessible, such as in the case of MicMac command-line operation (Verykokou et at., 2021); on the other, open-source codes often require constructing more complex workflows that integrate multiple tools and platforms. As such, the learning curve associated with open-source photogrammetry solutions is steep, necessitating further training. Moreover, some free platforms offer limited functionality when compared to commercial alternatives.

Professional commercial photogrammetry packages, such as Agisoft Metashape, RealityScan (formerly RealityCapture) and 3DF Zephyr, typically offer user-friendly interfaces alongside powerful processing capabilities to generate accurate, textured 3D models and an array of output options. Paid licenses are generally required to produce large models of buildings. A notable exception is RealityScan, which, as of 2025, is freely available to students, educators and most professionals, offering significant potential for users in low- and middle-income countries when computing infrastructure is available.

Despite advances over recent years, the execution of accurate photogrammetric workflows using free software in cloud-based

environments, particularly without access to a high-performance local machine, remains challenging. Limitations persist in terms of session duration, software functionality and user interface accessibility. Among the most economical options, platforms like Google Colab in combination with open-source photogrammetric tools, require higher levels of computing skills. Furthermore, cloud-based workflows are dependent on stable internet connections for data uploads, sustained session activity and visualization of outputs. In contexts such as Tunisia, limited internet reliability poses an additional constraint on the effective application of low-cost photogrammetry.

2.2 Capacity Building and Participation

The accessibility of data collection equipment has positioned photogrammetry as a promising tool for broad and collaborative use in heritage documentation, enabling the participation of diverse stakeholders that may include students, civil society and local communities. The training of heritage professionals and institutions in photogrammetric techniques has been well documented in the literature (e.g., Tse et al., 2019; Santana et al., 2020; Vileikis et al., 2023) and has become a standard component in the implementation of new heritage documentation projects, as well as in the training of upcoming professionals (Reina Ortiz et al., 2021).

Beyond formal training, the capacity building of non-professional groups has received growing attention. Ortiz Sanz et al. (2021) emphasize the efficacy of learning by doing through project-based learning (PBL), particularly suited to e-learning contexts. Tucci et al. (2018) describe a tiered training strategy in which communities including students, architects, historians or photographers are trained in photographic data collection, while the more technically demanding task of photogrammetric processing is undertaken by experts.

In the heritage sector, capacity building in documentation practices is often tied to broader objectives such as heritage values assessment, state of conservation of the surveyed asset, or management of digital twins (Tse et al. 2019), Capacity building is increasingly recognized, not only as a technical imperative, but also as an ethical responsibility (Santana et al., 2020).

Efforts aimed at expanding participation in heritage documentation often adopt crowdsourcing as the overarching strategy, inviting communities to contribute their photographs for the creation of digital models of heritage assets. Frequently involving local heritage authorities or responsible organizations, such initiatives vary in extent of community training provided, from minimal interventions such as signage around a heritage site encouraging visitor participation (Liu et al., 2022), to dedicated workshops focused on building photogrammetric data collection skills (Tucci et al., 2018).

3. Methodology

3.1 A Cross-disciplinary Framework for Revitalising Heritage Buildings

Documentation is an essential step in the framework developed under the ACTIVAH project for the community-centred, sustainable revitalisation of decayed heritage buildings within challenging contexts. This replicable framework is motivated by local civil society actors engaged in heritage, who see neglected historic buildings as opportunities for the reactivation of the urban landscape. It is conceived to be multidisciplinary and integrated, addressing essential issues of heritage values, building conservation or urban regeneration. Its application aims to be inclusive of local stakeholders and positive for the community. It is built around four interdependent areas of action: participation, heritage conservation, building dimension and urban reactivation (Fig. 2).

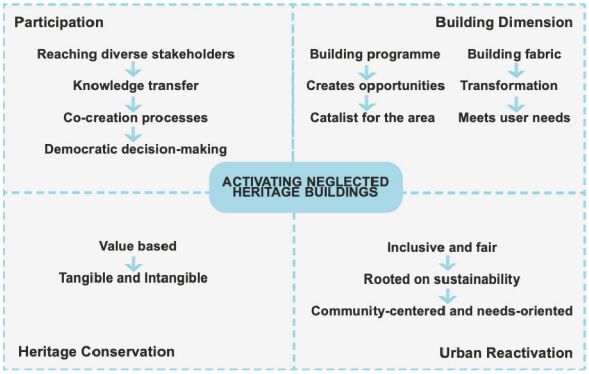

Figure 2. Strategic foci of the framework developed by ACTIVAH to support successful revitalization of neglected heritage buildings within historic urban environments.

The framework is tested on in-depth case studies that are representative of existing local challenges. The case studies are evaluated to understand: 1) the constraints; 2) the potential; 3) the needs; and 4) the possible strategies for their revitalization.

Documenting the built fabric is essential in this investigation: a) it offers the foundation for developing any work at the building scale, providing geometric and condition data essential for planning an intervention; b) it supports values assessment, supporting the recording of distinctive features of the building; c) it fosters participation of local communities in data collection; and d) it fosters engagement in heritage by providing a virtual record of the heritage building that can be disseminated and enjoyed by different stakeholders.

3.2 Collaborative Survey Methodology

The documentation of Fondok El Henna is a small-scale recording exercise that aims to be replicable within the financial, technical and logistical constraints of local civil society actors in the Medina of Tunis. Photogrammetry was selected for the documentation, not only for its suitability in capturing accurate geometric and textural features at multiple scales, but also for its potential to be integrated into low-resource contexts, thereby supporting sustainable and replicable approaches to the documentation of built heritage.

Terrestrial photogrammetry was deemed suitable for remote collaboration between Tunisia and UK partners. It aligned with the capacities of the Tunis-based partner, Blue Fish, who provided a technical team including an experienced photographer and the necessary photographic equipment, without the need for specialised data-collection equipment. The photographer received remote training by UCL partners, facilitating instruction in documentation procedures and photogrammetry image acquisition. This involvement ensured the successful execution of on-site image acquisition and reinforced the project's focus on strengthening local capacity in digital documentation. In the presence of access limitations due to the advanced state of decay in localised areas, and given the scope of the study, only one façade of Fondok El Henna was

documented (Fig. 3), representative of the building's overall character and condition.

Figure 3. Photogrammetric model of the façade, showing control points (yellow signs) at the corners of door openings. Gaps indicate areas that could not be captured due to visibility.

3.3 Data Collection and Capacity Building

Data collection at Fondok El Henna was undertaken using terrestrial photogrammetry as the principal method of heritage documentation. As part of the overall strategy for capacity building within the project, a structured digital workflow was established to ensure methodological consistency and replicability (Fig. 4). This included the development of a tailored technical guide — Digital Documentation Manual: Fondok El Henna Pilot Study — which outlined context-specific photographic acquisition protocols aimed at generating datasets suitable for accurate three-dimensional reconstruction and subsequent spatial analysis. The guide was informed by workflows developed by other authors, including methodologies proposed by Letellier (2007), Waldhäusl et al. (2013), Historic England (2017), and Santana Quintero et al. (2020).

To implement the workflow, a remote training session was delivered by heritage professionals from UCL to introduce the local team from Blue Fish to the theoretical and practical principles of photogrammetry, survey design, and expected deliverables. The session emphasised best practices in image acquisition, data organisation, and preliminary quality control, thereby promoting methodological rigour while enabling autonomous implementation. Beyond facilitating the immediate documentation process, the training contributed to local capacity building in digital documentation methodologies, aligning with broader objectives of community engagement and the sustainable management of built heritage.

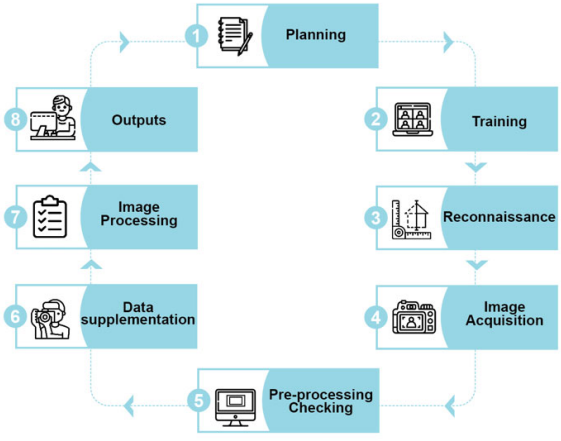

Figure 4. Photogrammetric digital workflow. Stages include: planning; training; site reconnaissance; image acquisition; pre-processing and quality checks; completion of missing data/images; model generation; and final outputs.

Prior to image acquisition, the local team conducted a reconnaissance survey to assess environmental and physical factors that could influence image quality, including lighting conditions, surface textures, and access constraints. A video walkthrough of the site was recorded and shared with the UCL team to support collaborative planning and preliminary quality assurance. Based on this initial assessment, the photographic strategy — as developed in the Digital Documentation Manual: Fondok El Henna Pilot Study — was refined to address challenges associated with the building's configuration, restricted access areas, movable furniture, and the presence of pedestrian traffic throughout the site.

Photographs were captured using a high-resolution digital camera (Table 1), set to manual mode, with an appropriate shutter speed and aperture, and a low ISO value. Images were taken with sufficient overlap, with frontal overlap ranging from 60% to 70%, adjusted according to the complexity of the architectural features. At ground level, images were taken from approximately 3.5 metres. A similar distance was intended for the second floor; however, as the photographs were taken from the upper level, the average distance increased to around 5 metres. Control targets were manually placed on distinctive architectural elements to assist with image alignment. In the absence of printed or commercial control markers, temporary reference points such as yellow post it notes were affixed to the corners of openings (Fig. 3). Due to budgetary constraints, a total station was not available to provide precise geospatial control via three dimensional measurements.

Category	Model / Description
Camera model	Sony Alpha 7 III with 35mm full-frame 24MP image sensors
Camera lenses	Sony G 24–105mm lens, shot at f7.1, ISO 100
Camera tripod	Weifeng WF-6663A
Shutter release & monitor	iPhone 12 and iPad 8
Control targets	3M Post-it notes with drawn cross
Sensor resolution	24.2 MP, full-frame CMOS
Focal length [mm]	35 mm (fixed)
Number of images	Approx. 160 images (80 initial + 80 complementary)
Acquisition time [min]	Initial: 60 min, Follow-up: 60 min

Table 1. Dataset and Equipment Used

Following fieldwork, the initial image set was transferred to UCL for processing. Pre-processing was conducted using Agisoft Metashape Professional, following standard photogrammetric stages: image import, alignment, filtering, error checking, dense point cloud generation, and mesh creation. The resulting low-resolution point cloud revealed areas of insufficient coverage, particularly in zones with limited overlap or visual obstructions. To address these gaps, a complementary image set was acquired during a follow-up site visit and processed using the same workflow to ensure methodological consistency. The final dataset produced a complete dense point cloud and a textured 3D mesh model, consolidating a systematic and replicable low-cost documentation approach.

3.4 Condition Assessment of Fondok El Henna

The photogrammetric model served as the basis for the remote assessment of the condition of the façade fabric, providing a visually rich and detailed reference that enabled the identification of existing materials and construction features. Although not geospatially referenced, the model supported a

preliminary visual inspection and helped define the scope and focus areas of the conservation study (Fig. 5).

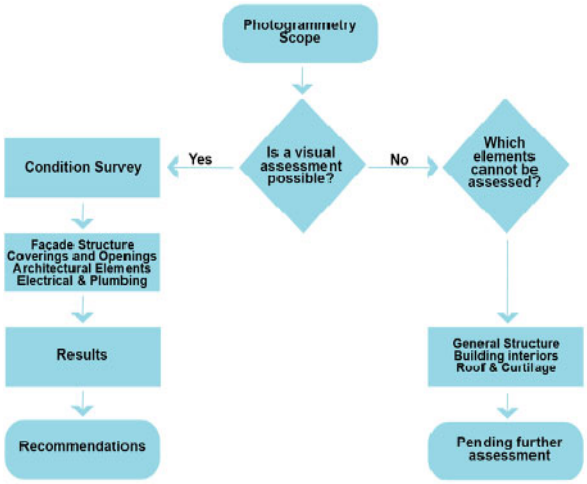

Figure 5. Flow chart illustrating the scope of the photogrammetric process, specifying which elements were eligible for condition survey and which were excluded due to technical limitations.

This assessment was carried out by building conservators at UCL, who examined high-resolution orthophotos generated from the 3D model to evaluate the visible condition of the façade. Key elements analysed included the structural fabric, surface coverings, window and door openings, architectural details, and the integration of electrical and plumbing systems. Observations were annotated directly on the images using Adobe Photoshop to indicate areas of damage or concern (Fig. 6), showing the value of photogrammetric outputs as tools for remote expert analysis, particularly in settings with limited access or resources.

Figure 6. Conservation state of building elements. The top image shows the original condition, while the bottom shows damage mapping by priority. Damage levels are indicated by colour, as defined in Figure 6.

The condition assessment revealed that water ingress, pollution, biological growth, light exposure, and anthropogenic activity were the primary agents of deterioration affecting the façade. These factors contributed to various patterns of damage, with moisture accelerating material decay in areas where protective coatings had failed. Pollutants and organic growth, such as mosses and lichens, were observed in shaded or poorly ventilated sections, while sunlight caused fading and surface erosion. Additional signs of human-induced damage, including mechanical wear and informal electrical installations, were also identified. The severity of deterioration was documented using a colour-coded scale (Fig. 7), enabling the prioritisation of interventions according to the condition of each element. Each colour corresponds to a numerical range based on the number of deterioration agents present. For example, a 'good' condition, defined as no damage or no visible damage, is represented by a value between 0 and 1. This analysis informed a graduated response strategy, ranging from routine maintenance to emergency works. Overall, the façade was found to be in poor condition, with several areas showing advanced deterioration.

DAMAGE LEVEL	CONDITION ASSESSMENT	PRIORITY
	Good state of conservation, due to no damage or no visible damage. A number of deterioration agents range from 0 to 1.	Normal Maintenance work
	Fair state of conservation because it presents minor damages or superficial defects. Number of agents of deterioration from 2.	Routine Single repairs
	Poor state of conservation, because of relevant damage, but not affecting its functioning. Number of agents of deterioration at 3	Necessary Minor repairs
	Very poor state of conservation with severe damage that may affect its functioning. Number of agents of deterioration to 4.	Urgent Major repairs

Figure 7. Conservation condition assessment, damage level and priority.

4. Discussion

4.1 A Critique of the Documentation Process and Its Findings

The pilot case study of the Fondok El Henna in the Medina of Tunis confirmed the viability of a low-cost collaborative documentation and damage assessment strategy developed through a remote–local cooperation model between civil society and academia. The effectiveness is nonetheless dependent on certain limitations and the results were partial.

Notable limitations were related to access and visibility at Fondok El Henna. Restricted physical access to the site was a concern, due to: a) structural safety concerns, given the state of conservation; b) constant pedestrian flow in the immediate surroundings; and c) COVID-19 health measures, as the recording was carried out in spring and summer 2021. These conditions limited data collection to a single façade and confined fieldwork to Sunday mornings, when foot traffic was lowest. The narrow framework for data acquisition led to image capture under high-contrast conditions, resulting in strong shadows and gaps in the 3D model. In addition, the presence of furniture and surrounding obstacles hindered image sequencing and compromised the spatial coverage of the photogrammetric survey. Notably, it was not possible to document the roof. To address similar constraints in future case studies, it is recommended to conduct preliminary accessibility assessments to align project scope with on-site conditions and to coordinate with local stakeholders and responsible entities to grant access to necessary areas at suitable sunlight times, and clear key areas. Furthermore, complementary technologies can be used to access hard-to-reach areas. Within low-cost settings, the use of drones may not be possible for documenting high areas. Other affordable options such as poles or surveying from neighbouring buildings should be considered.

The project offered the opportunity to develop an iterative remote-training approach that involved rounds of training-data

collection-data testing that could be adapted to the needs identified. Due to time and access constraints, the final dataset had some gaps, highlighting the need for further support in data collection.

4.2 Working with Limited Economic and Technological Resources

As discussed in section 2.1, while terrestrial photogrammetry is a low-cost documentation option, it requires a minimum investment that can be limiting in certain low- and middle-income environments and fragile contexts.

This pilot project demonstrates the potential scalability and replicability of a modular, low-cost photogrammetric methodology designed for heritage sites operating under resource constraints. Its principal strengths—adaptability, low entry threshold, and reliance on local actors—make it a viable alternative in contexts where conventional documentation methods may be unfeasible or inaccessible. Although a remote–local photogrammetric workflow using low-cost, accessible tools was proposed, the experience showed that many of these resources were less affordable and available than anticipated.

The local team had access to a professional photographer and high-end camera, conditions not always replicable in similar contexts. Computing equipment and software Agisoft Metashape Professional employed for image processing was not available locally, which led to processing being conducted at UCL. While alternative open-source workflows could be proposed, e.g. Meshroom, OpenMVG, or COLMAP, the need for high-performing computing hardware remains a challenge. Follow-up experience in training upcoming heritage professionals at the University of Tunis in the use of photogrammetry with free licenses in October 2023 demonstrated that computing facilities at university level represent a challenge locally, hindering students progress in PBL. Cloud-based computing is not an easily viable alternative, as stable internet connections are not readily available locally and the steeper learning curve required would render training less accessible.

The absence of a total station further limited the metric accuracy of the model. Alternative more accessible triangulation methods would be preferable for low-resource settings. Scale bars may be used to assist with triangulation and ensure spatial accuracy.

4.3 Civil-Society Led Documentation: Contribution

A particularity of the ACTIVAH project and case work is that it was promoted by local civil society stakeholders that hold limited power in the legal governance structure of publicly or third-party owned built heritage. These stakeholders, however are essential for heritage conservation in fragile environments as multi-stakeholder partnerships are increasingly recognised as one of the few viable options for revitalization of neglected buildings in historic urban contexts with public resource constraints (Albuerne et al., 2025). They have an active and audible voice in advocating for heritage and an unrivalled capacity to mobilise communities when they can demonstrate aligned interests.

Local partner Blue Fish, a a Tunisian social enterprise dedicated to community and economic development through cultural revitalization, played a crucial role in this project as link between the international academic team and local stakeholders, including the local community and academia. The Blue Fish team played a key role in defining the research question and facilitating knowledge transfer and local involvement throughout the project.

The case study assessment findings, which were shared with the local community, corroborated the concerns over the longevity of Fondok El Henna and served the local stakeholders as an advocacy tool to raise awareness of the immediate needs of the buildings and as instrument for leveraging support.

Within these contexts, it is interesting to explore the roles that heritage documentation can play in the case of neglected buildings in fragile contexts. Digital records such as that of Fondok El Henna are highly valuable for local communities and civil society stakeholders:

1. Memory. Heritage digital records capture the reality of a historic building at a particular instance. This serves to recall what the site was like after time, when it is potentially lost, or for story-telling.
2. Advocacy. A digital record of a decayed building is data that can be easily shared with decision makers and potential funders to leverage action.
3. Building conservation. The detailed documentation and condition mapping holds necessary information for developing conservation projects, assessing needs and estimating costs.

4.4 Implications and Directions for Future Research

The experience at Fondok El Henna represents an initial attempt to develop a transferable model, applicable both within the World Heritage Site of the Medina of Tunis and in similar contexts internationally. Its implementation elsewhere requires careful consideration of the technical, social, and economic conditions specific to each site. Key enabling factors include unrestricted access, sufficient time for data collection, favourable environmental conditions, and the availability of basic technical resources—namely, a digital camera, tripod, computer with adequate processing capacity, accessible or institutional photogrammetry software, and a local team with fundamental digital photography skills.

In that sense, collaboration with local stakeholders—such as community organisations or social enterprises—is not merely a supplementary support but constitutes a fundamental element of long-term sustainability. Such collaboration ensures the approach is rooted in local socio-cultural realities, fosters community ownership of the process, and strengthens local capacity, all of which are essential to maintaining the work’s relevance beyond the initial intervention. While the methodology may remain viable in more constrained environments where some of these conditions are lacking, its application may require a greater degree of external support. In the case of Fondok El Henna, the absence of local infrastructure for data processing and heritage documentation professionals was mitigated through remote instruction, external technical assistance, and the active involvement of a local civil society group.

Successful local implementation of the methodology also depends on a clearly defined minimum skill set and baseline resources. Participants should be familiar with the manual operation of digital cameras—particularly in adjusting key parameters such as focus, exposure, and image overlap—and be capable of planning photographic routes and systematically organising the captured data. Essential equipment includes a digital camera, a tripod to ensure image stability, and a

computer with adequate processing power. While open-source software may be employed, its performance should be evaluated in advance to ensure suitability for technical tasks such as condition surveys; alternatively, image processing can be outsourced to collaborating institutions. Although formal professional training is not a prerequisite, the process relies on effective initial instruction and a commitment to ongoing learning. The presence of a basic local coordination structure and the use of context-specific materials—such as the Digital Documentation Manual: Fondok El Henna Pilot Study—could play a key role in fostering community ownership and sustained engagement with the methodology.

Future research to contribute to a deeper understanding of the potential of photogrammetry for community-led documentation of endangered heritage should seek to explore its application across a wider variety of settings with differing levels of constraints, in order to test and refine the workflow and to identify the minimum conditions necessary for effective implementation. Beyond technical feasibility, it is invaluable to evaluate the long-term impact of such initiatives in terms of capacity building, community engagement and sustainable heritage management. Ultimately, the replicability of this approach depends not only on access to equipment and software but also on a commitment to inclusive collaboration and the ability to adapt methods and objectives to the specific realities of each context.

5. Conclusions

This paper explores the development and implementation of a replicable low-cost, community-oriented photogrammetry workflow for documenting endangered heritage buildings in the Medina of Tunis. Through the case study of Fondok El Henna, the research demonstrates the feasibility and value of civil society-led documentation initiatives that rely on accessible tools, remote collaboration and context-sensitive training. The project confirms that even in settings marked by economic and technological constraints, effective documentation is possible when supported by local partnerships, tailored capacity building, and methodological adaptability. While the recording process faced limitations due to physical access, hardware availability, and local computing infrastructure, these were mitigated through cross-institutional collaboration, remote instruction, and iterative field engagement.

The findings underscore the potential of digital documentation not only as a conservation tool but also as a catalyst for advocacy, knowledge transfer, and community empowerment. Photogrammetric records, when shared with stakeholders, can serve to raise awareness, support fundraising efforts, and guide conservation planning. However, the challenges encountered, particularly in terms of access to computing resources and technical infrastructure, highlight the need for further development of lightweight, affordable workflows that minimize dependency on external expertise. The experience reinforces the critical role of local civil society actors in initiating, sustaining and disseminating heritage interventions in fragile urban environments.

Future research should aim to expand the testing of this approach across diverse settings, with an emphasis on assessing long-term impacts on community capacity, participation and sustainable heritage management. Ultimately, inclusive and scalable documentation strategies like the one presented here offer a meaningful pathway toward preserving heritage in under-resourced and at-risk contexts.

Acknowledgements

The authors thank all members of the ACTIVAH research team and collaborators, including local stakeholders and Fondok el Henna artisans. A special thanks to the Blue Fish team and to photographer Amine Hamouda. The authors also thank UCL's Global Challenges Research Fund for funding the research.

References

Albuerne, A. Quijano Quinones, E., Safaie, Y., Fouseki, K., Ortiz, C., Saadi, N., Chachia, H., Ben Gacem, L., 2025: Challenging Partnerships: Complexities & Obstacles in Multi-Stakeholder Participation in Revitalizaing Heritage Buildings in the Medina of Tunis. In Pereira Roders, A., Cunha Ferreira, T. (Coord.), 2025: *Faro Convention International Conference 2024 Proceedings*, Porto (in print).

Balado, J., Garozzo, R., Winiwarter, L., Tilon, S., 2025: A systematic literature review of low-cost 3D mapping solutions. *Information Fusion*, 114, Article 102656. doi.org/10.1016/j.inffus.2024.102656.

Chachia, H., 2021. Fondok El Henna: Activating Heritage in the Medina of Tunis. Film by Amine Hamouda. 7 December 2021. www.youtube.com/watch?v=QIQAOX2zonU (Accessed: 10 June 2025).

Chmour, M., 2021. Fondok El Henna: Activating Heritage in the Medina of Tunis. Film by Amine Hamouda. 7 December 2021. www.youtube.com/watch?v=QIQAOX2zonU (Accessed: 10 June 2025).

Cruz, M., 2021. Remote documentation and monitoring strategies for the sustainable conservation of a Medina of Tunis building. MSc Sustainable Heritage, University College London.

Dhonju H.K., Xiao W., Sarhosis V., Mills J.P., Wilkinson S., Wang Z., Thapa L., Panday U.S., 2017: Feasibility study of low-cost image-based heritage documentation in Nepal. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci*., XLII-2/W3, 237–242. doi.org/10.5194/isprs-archives-XLII-2-W3-237-2017.

Elkhrachy, I. 2020: Modeling and Visualization of Three Dimensional Objects Using Low-Cost Terrestrial Photogrammetry. *International Journal of Architectural Heritage*, 14(10), 1456–1467. https://doi.org/10.1080/15583058.2019.1613454

ICOMOS, 1996. Principles for Recording of Monuments, Groups of Buildings and Sites. 11th ICOMOS General Assembly, Sofia, Bulgaria, 5-9 October. www.icomos.org/en/resources/charters-and-texts (20 March 2025).

Khalloufi K., Azough A., En-Nahnahi N., Kaghat F., 2020: Low-cost terrestrial photogrammetry for 3D modeling of historic sites: A case study of the Marinids' Royal Necropolis, city of Fez, Morocco. *Mediterranean Archaeology and Archaeometry*, 20(3), 257–272. doi.org/10.5281/zenodo.3930412.

Historic England, 2017. Photogrammetric Applications for Cultural Heritage. Guidance for Good Practice. historicengland.org.uk/images-

books/publications/photogrammetric-applications-for-cultural-heritage/ (10 June 2025).

Letellier, R., Schmid W., LeBlanc F., 2007. Recording, Documentation, And Information Management for the Conservation of Heritage Places. Los Angeles: Getty Conservation Institute. hdl.handle.net/10020/gci_pubs/recordim (05 June 2025).

Liu, Z., Brigham, R., Long, E. R., Wilson, L., Frost, A., Orr, S. A., Grau-Bové, J., 2022: Semantic segmentation and photogrammetry of crowdsourced images to monitor historic facades. *Heritage Science*, 10(1), Article 27. doi.org/10.1186/s40494-022-00664-y.

McGuinness, J., 1997: Political Context and Professional Ideologies: French Urban Conservation Planning Transferred to The Medina of Tunis. *The Journal of North African Studies* 2(2), 34–56. doi.org/10.1080/13629389708718295.

Mezzino, D., Chan, L., Santana Quintero, M., Esponda, M., Lee, S., Min, A., and Pwint, M., 2017: Built heritage documentation and management: An integrated conservation approach in Bagan, *ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci.*, IV-2/W2, 143–150, doi.org/10.5194/isprs-annals-IV-2-W2-143-2017.

Mohareb, N., Alsalloum, A., Webb, N., 2023: A morphological analysis of historic buildings entries using affordable photogrammetry techniques: Old Tripoli, Lebanon. *Digital Applications in Archaeology and Cultural Heritage*, 28, e00261. doi.org/10.1016/j.daach.2023.e00261.

Municipalité de Tunis, n.d. Plan d’aménagement. www.permisconstruire.tn/plan.jsp (05 June 2025).

Murtiyoso, A., Grussenmeyer, P., Suwardhi, D., 2019: Technical Consideration in Low-cost Heritage Documentation. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII-2/W17, 225–232. doi.org/10.5194/isprs-archives-XLII-2-W17-225-2019.

Ortiz-Sanz, J., Gil-Docampo, M., Rego-Sanmartín, T., Arza-García, M., Tucci, G., 2021: A PBeL for training non-experts in mobile-based photogrammetry and accurate 3-D recording of small-size/non-complex objects. *Measurement : Journal of the International Measurement Confederation*, 178, Article 109338. doi.org/10.1016/j.measurement.2021.109338.

Reina Ortiz, M., Santana Quintero. M., Vernaza, C., Ramírez, P., Montejo Gaitán, F., Segura Escobar, J., 2021: Capacity building for the documentation and conservation of Latin American cultural heritage: Making technology accessible and sustainable. *Journal of Cultural Heritage Management and Sustainable Development*, 11(2), 155–169. doi.org/10.1108/JCHMSD-05-2020-0076.

Santana Quintero, M., Awad, R. Barazzetti, L., 2020: Harnessing digital workflows for the understanding, promotion and participation in the conservation of heritage sites by meeting both ethical and technical challenges. *Built Heritage*, 4(1): 6. doi.org/10.1186/s43238-020-00005-7.

Tse, D., Paladini, A., Dhanda, A., Weigert, A., Reina Ortiz, M., Santana Quintero, M., Min, A., Gyi, M., Su, S., 2019: Conserving Built Heritage for Posterity: A Conservation Approach in Bagan. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences.*, XLII-2/W15, 1179–1185. doi.org/10.5194/isprs-archives-XLII-2-W15-1179-2019.

Tucci, G., Conti, A., Fiorini, L., Mei, F., Parisi, E. I., 2018: Digital Photogrammetry as a Resource for Cuban Cultural Heritage: Educational Experiences and Community Engagement within the INNOVA Cuba Project. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences.*, XLII–5, 37–44. doi.org/10.5194/isprs-archives-XLII-5-37-2018.

UNESCO, n.d. Medina of Tunis. UNESCO World Heritage Center. whc.unesco.org/en/list/36 (20 March 2025).

Verykokou, S., Soile, S., Bourexis, F., Tokmakidis, P., Tokmakidis, K., Ioannidis, C., Ioannides, M., Cantoni, L., Champion, E., Fink, E., 2021: A Comparative Analysis of Different Software Packages for 3D Modelling of Complex Geometries. In *Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection* (pp. 228–240). Springer International Publishing. doi.org/10.1007/978-3-030-73043-7_19.

Vileikis, O., Rigauts, T., Rouhani, B., Ziane Bouziane, M., Santana Quintero, M., 2023: Dive into Heritage: A Digital Documentation Platform of World Heritage Properties in the Arab States Region. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLVIII-M-2–2023, 1613–1620. doi.org/10.5194/isprs-archives-XLVIII-M-2-2023-1613-2023.

Waldhäusl, P., Ogleby, C. L., Lerma, J. L. & Georgopoulos, A., 2013. 3×3 rules for simple photogrammetric documentation of architecture. CIPA Heritage Documentation. Available at: https://www.cipaheritagedocumentation.org/wp-content/uploads/2017/02/CIPA__3x3_rules__20131018.pdf