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DIGITAL DOCUMENTATION OF URBAN HERITAGE IN CAIRO: A STUDY OF BAB AL-BARQIYYA AND ITS APPLICATION IN MODERN REHABILITATION PRACTICES

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ABSTRACT

This study investigates how digital technologies support the preservation of historic urban architecture in Cairo, focusing on the Fatimid-era gate, Bab al-Barqiyya. As part of a restoration project by the Aga Khan Trust for Culture, the gate serves as a key example of merging traditional conservation with modern tools like photogrammetry and 3D visualization. The research examines methods such as image-based modeling and point cloud analysis to document structural issues and material decay. To test broader applicability, a simplified workflow using accessible software like Polycam and CloudCompare is applied to a second site, Bab al-Nasr. This practical experiment evaluates whether students or local heritage teams can perform basic documentation and assessment using low-cost tools. The findings emphasize the value of affordable digital workflows in heritage conservation, particularly in contexts where advanced scanning technologies are unavailable, thus offering scalable solutions for preserving cultural landmarks in resource-constrained settings

KEYWORDS: Architectural heritage, photogrammetry, Digital Documentation, image-based modeling, heritage conservation

التوثيق الرقمي للتراث العمراني في القاهرة: دراسة حالة باب البرقية وتطبيقاتها على الممارسات الحديثة لاعادة تأهيل التراث

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الملخص

تتناول هذه الدراسة دور التقنيات الرقمية في دعم حفظ العمارة الحضرية التاريخية في القاهرة، مع التركيز على بوابة باب البرقية من العصر الفاطمي. وكجزء من مشروع ترميم تقوده مؤسسة الآغا خان للثقافة، تُعد البوابة مثالًا رئيسيًا على دمج تقنيات الحفظ التقليدية مع الأدوات الرقمية الحديثة مثل الفوتوغراميتري والتصوير ثلاثي الأبعاد. تبحث الدراسة في طرق التوثيق المستخدمة، مثل النمذجة المعتمدة على الصور وتحليل السحب النقطية، لتوثيق

المشكلات الإنشائية وتدهور المواد. ولاختبار قابلية التطبيق على نطاق أوسع، تم استخدام سير عمل مبسط يعتمد على برامج يسهل الوصول إليها مثل Polycam وCloudCompare في موقع تراثي آخر هو باب النصر. ويهدف هذا التطبيق العملي إلى تقييم قدرة الطلاب أو فرق التراث المحلية على إجراء التوثيق الأساسي وتقييم الحالة باستخدام أدوات منخفضة التكلفة. وتؤكد النتائج على أهمية استخدام أساليب رقمية ميسورة التكلفة في حفظ التراث، خاصة في البيئات التي تفتقر إلى تقنيات المسح المتقدمة، مما يوفر حلولًا قابلة للتوسع للحفاظ على المعالم الثقافية.

الكلمات المفتاحية : التراث المعماري، القياس التصويري، التوثيق الرقمى، النمذجة المعتمدة على الصور، الحفاظ على التراث.

1. INTRODUCTION

Urban heritage in historic cities such as Cairo faces increasing threats from rapid urbanization, environmental degradation, and insufficient maintenance due to limited financial and institutional resources. As a result, the need for accurate and sustainable documentation methods has become more urgent than ever. Traditional heritage recording techniques, including hand-drawn surveys and manual measurements, although reliable, are labor-intensive and often inadequate for capturing the complexity of historic architectural forms [1]. In response, digital technologies, particularly photogrammetry, point cloud modeling, and 3D visualization have gained prominence for their ability to deliver precise, scalable, and replicable documentation [2].

Among these, image-based modeling and photogrammetry stand out as affordable and accessible alternatives to more sophisticated technologies like LiDAR or AI-based diagnostic tools [3]. However, despite their potential, such technologies are still underutilized in local or community-driven preservation contexts, where technical expertise and funding are limited [4]. This research seeks to bridge that gap by proposing and evaluating a simplified digital documentation workflow that leverages open-source tools and low-cost methodologies.

The study focuses on the restoration of Bab al-Barqiyya, a Fatimid-era gate in Cairo, which was conserved as part of the al-Darb al-Ahmar Urban Renewal Project led by the Aga Khan Trust for Culture. This case provides an exemplary model of integrating traditional conservation with digital recording techniques [5]. The research then applies a comparable digital workflow based on accessible application and software such as Polycam and CloudCompare to a second historic structure in Cairo which is Bab Al-Nasr. The objective is to assess whether such methods can produce reliable, outcomes that support urban heritage preservation efforts in data-scarce and low-resource settings.

2. METHODOLOGY

This research employed a comparative, practice-based methodology combining visual analysis, digital reconstruction, and field documentation to evaluate the effectiveness of accessible digital tools in heritage conservation. The first phase focused on the documented restoration of Bab al-Barqiyya, analyzing architectural drawings, and available 3D datasets produced during the Aga Khan Trust for Culture's intervention.

In the second phase, a practical digital workflow was applied to Bab al-Nasr using photogrammetry. High-resolution, overlapping photographs of the monument were captured and processed using Polycam, an open-source photogrammetry mobile application. The resulting 3D model was further analyzed in CloudCompare software to generate elevation maps, profile sections, and surface visualizations. This allowed for the identification of material deterioration and structural irregularities. The methodology was selected to test whether such low-cost, open-source tools could enable non-specialists to produce reliable digital records and conduct basic condition assessments of architectural heritage. The methodology is structured as shown in **Fig. 1**.

The research acknowledges that the simplified photogrammetry approach may not match the precision of LiDAR or AI-driven methods. However, the focus remains on usability, replicability, and cost-effectiveness for educational and grassroots heritage preservation initiatives.

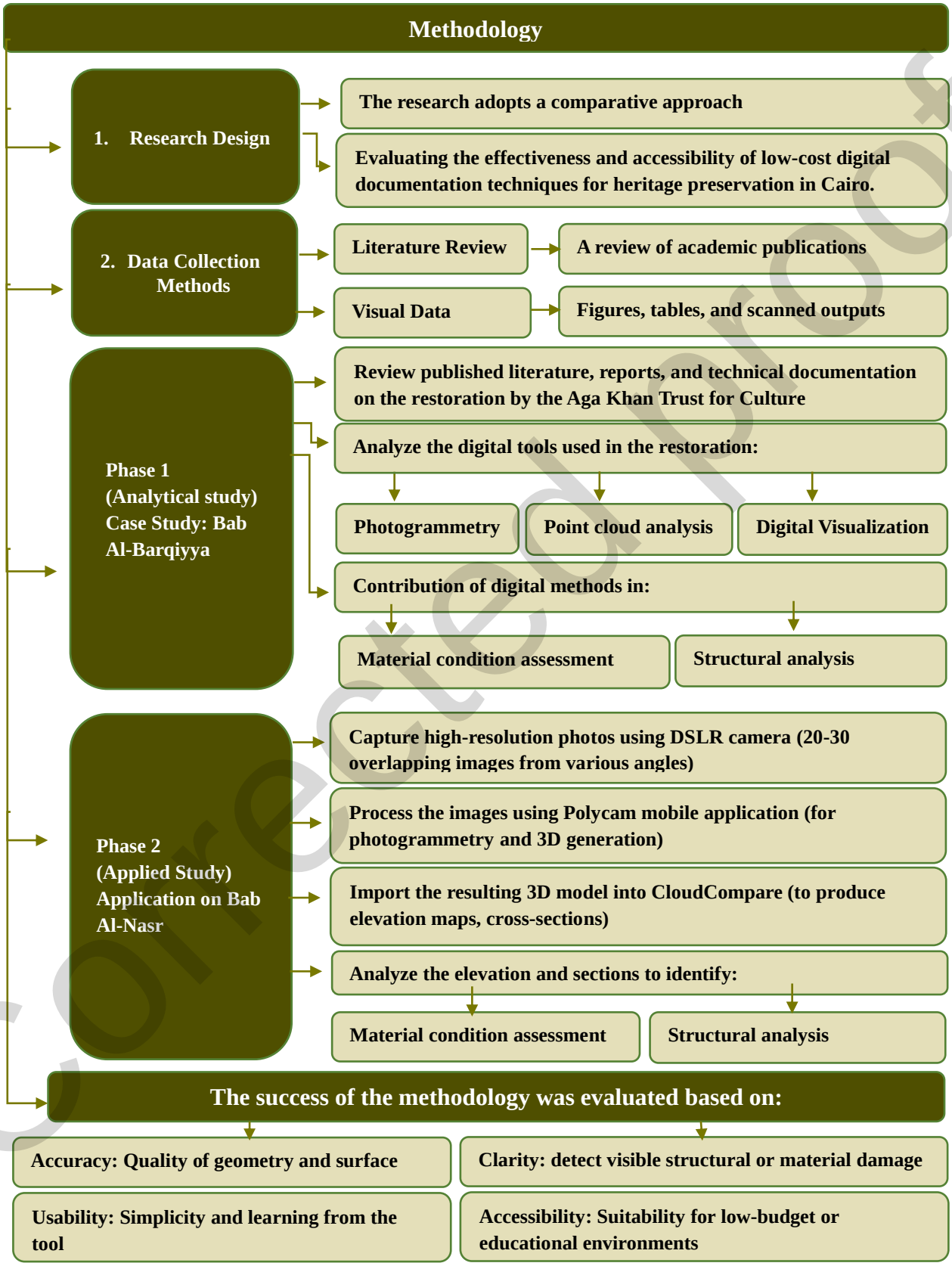


Fig. 1: Research Methodology

3. LITERATURE REVIEW

3.1 Heritage buildings Classification in Egypt

In Egypt, the classification of heritage buildings (such as Category A, B, or C) is overseen by the Ministry of Tourism and Antiquities (MoTA) through its affiliated body, the Supreme Council of Antiquities (SCA), which is officially responsible for managing and protecting the country's cultural and architectural heritage [6]. Additionally, the National Organization for Urban Harmony (NOUH), operating under the Ministry of Culture, plays a key role in the classification and protection of architecturally and historically significant buildings that are not registered as antiquities but still possess heritage value [7]. NOUH classifies buildings into three main categories as shown in **Table 1**:

Table 1: Historic buildings Classification in Egypt

Historic buildings classification in Egypt		
Category (A)	**Category (B)**	**Category (C)**
Buildings of exceptional historical or architectural value.	Buildings of moderate heritage value.	Buildings with local or contextual significance.
No structural modifications allowed.	Limited modifications permitted with official approval.	More flexible modifications allowed.
Examples: Bab AL-Barqiyya, Bab Al-Nasr	**Examples**: Known palaces in Cairo or Alexandria.	**Examples**: Historic residential buildings in older neighborhoods.

Historic Cairo is inscribed on the UNESCO World Heritage List since 1979 due to its exceptional testimony to the cultural, architectural, and urban legacy of Islamic civilization. The area encompasses a dense fabric of historic buildings, mosques, madrasas, hammams, and residential structures that reflect successive historical periods from the Fatimid to the Ottoman era. This global recognition underscores the international value and urgency of preserving such a unique urban heritage. Therefore, any documentation or rehabilitation work carried out within this context such as that of Bab al-Barqiyya must align with UNESCO's guidelines and international standards for conservation and cultural heritage protection [8].

3.2 The Rehabilitation of Heritage Buildings

Rehabilitation is considered one of the Heritage conservation standards which mean the wise management of function and potential changing. Rehabilitation strives to bring heritage sites into the modern world without damaging any historic elements. Rehabilitation is a multi-disciplinary process that builds upon prior intervention stages (like preservation, restoration, or reconstruction) [9]. These preliminary standards prepare historic buildings for architectural rehabilitation, which then adapts them for contemporary use through strategic alterations and additions as **Fig. 2**.
Unlike the previous standards, Rehabilitation uniquely allows modifications and additions to adapt historic structures for modern functional use while preserving their heritage value.

Rehabilitation can vary from preventative maintenance and minor repairs to major modifications (like partial demolition or structural changes) to adapt a building for new uses. A compatible design integrates new elements while preserving key historical features such as scale, color, massing, proportions, and materials creating a harmonious connection between old and new [9].

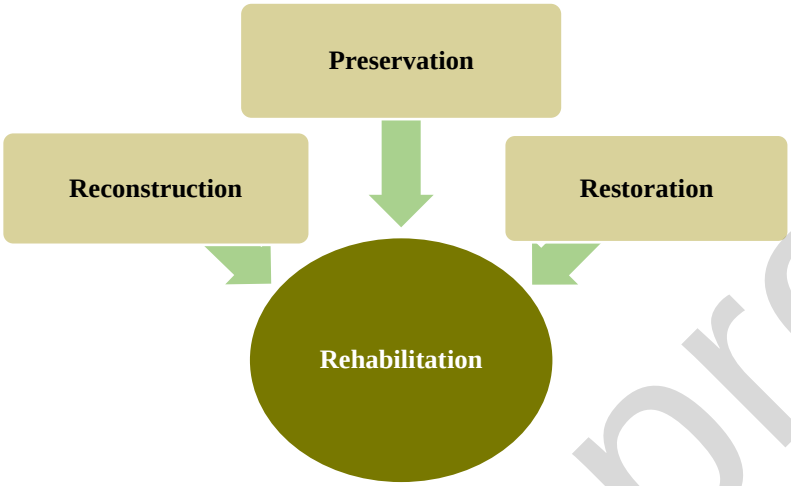


Fig. 2: The preliminary standards before rehabilitation

2.3 The Rehabilitation Phases

Rehabilitation is a particular process that requires careful planning and execution. Here are the general phases involved in heritage buildings as shown in **Fig. ٣**:

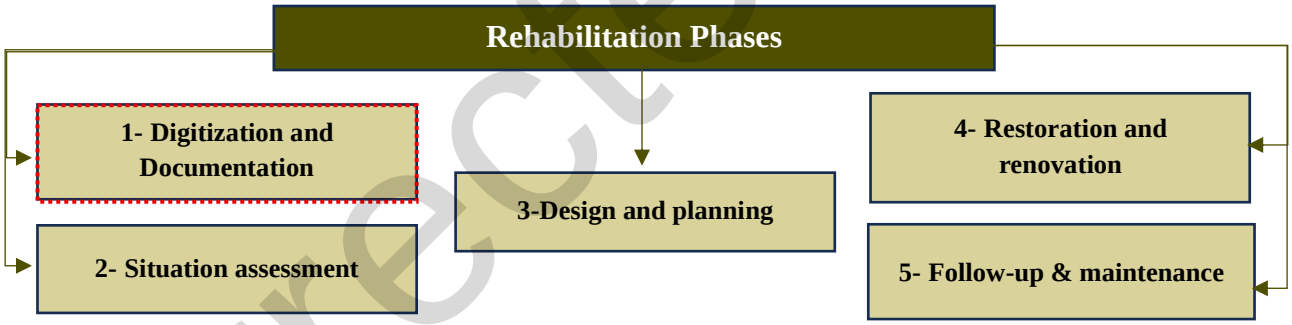


Fig. 3: Rehabilitation phases

3.4 Digitization and Documentation

The intersection of digital documentation and architectural heritage represents one of the most promising frontiers in cultural preservation and design innovation. As digital documentation technologies advance, they're being increasingly applied to document, analyze, restore, and reinterpret historical architecture in ways that were previously impossible [10].

Digital documentation, especially photogrammetry, offers an effective solution for preserving architectural detail while minimizing physical intervention. As an image-based method, photogrammetry uses overlapping photographs to reconstruct 3D models of physical spaces with sub-centimeter accuracy, where accuracy refers to the positioning error between the digital model and the actual physical object. [11]. Unlike LiDAR, which requires costly equipment and advanced technical skills, photogrammetry is affordable, requires only basic photographic equipment, and is

supported by several open-source software platforms, making it ideal for application in low-resource settings [2]. Each tool works as the following:

- LiDAR (Light Detection and Ranging) Scanning:
  It works like RADAR but by emitting laser beams that reflect off surfaces, with distance calculated via time-of-flight, reflectivity, and texture. The collected data forms a 3D point cloud, enabling detailed stereographic visualization. For example, LiDAR can map a building's walls by scattering billions of points, capturing shape and form accurately [12].
  For example, LiDAR scanning used in documenting and planning the restoration of Notre-Dame Cathedral as shown in **Fig. 4**.

Fig. 4: LiDAR scanning played used in documenting and planning the restoration of Notre-Dame Cathedral, [13]

- Photogrammetry (Drone & AI-Assisted):
  Photogrammetry has emerged as one of the most accessible and cost-effective methods for the digital documentation of architectural heritage. It involves the process of capturing multiple overlapping photographs from different angles and using computer algorithms to reconstruct a three-dimensional model of the object or structure. Unlike LiDAR scanning, which requires expensive hardware and specialized training, photogrammetry can be performed using basic photographic equipment, making it particularly suitable for use in resource-constrained environments [14].

For Example, **Fig. 5** and **Fig. 6** illustrates a 3D texture mapping for a historic space.

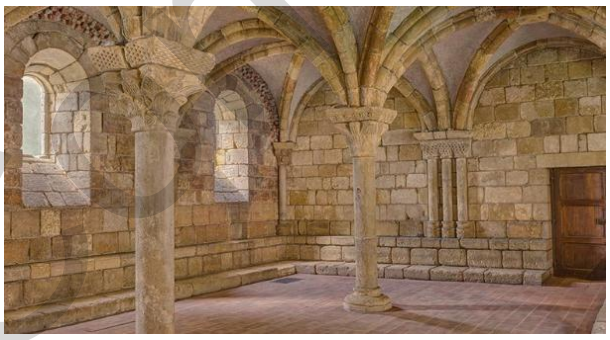


Fig. 5: Photogrammetry 3D Mesh of Historic Space - with textures [15]

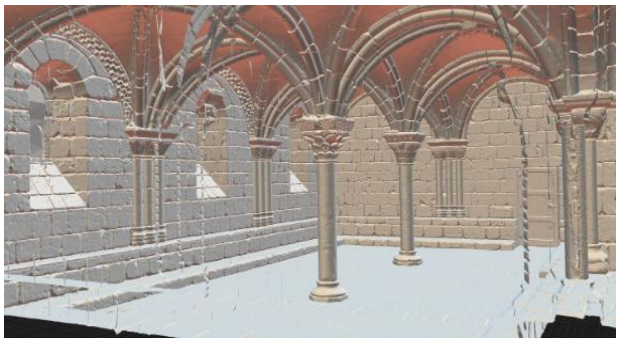


Fig. 6: Photogrammetry 3D Mesh of Historic Space without textures [15]

3. ANALYTICAL STUDY

The analytical phase of this research focused on assessing the material and structural condition of Bab al-Barqiyya through a combination of photogrammetric modeling and point cloud analysis. Using datasets derived from image-based modeling, detailed visualizations were generated to identify surface deformations, material loss, and architectural discontinuities. Colorized point clouds enabled a visual distinction between elevation levels, where abrupt changes in coloration particularly around the upper towers and vaulted entries indicated zones of surface erosion, partial collapse, and stone displacement. Structural sections and orthographic projections revealed deformations in the arches and weakened masonry joints, supporting findings of previous interventions by the Aga Khan Trust for Culture. This digital analysis not only validated historical documentation but also provided a non-invasive methodology for diagnosing heritage vulnerabilities with high spatial accuracy.

3.3 Case study

Bab al-Barqiyya is one of the most significant surviving examples of Fatimid military architecture in Historic Cairo, reflecting the city's strategic and symbolic urban design during the Islamic Middle Ages. Located near the eastern edge of the old city, close to today's al-Azhar Park, the gate was originally constructed in the 11th century CE as part of Cairo's eastern defensive walls commissioned by the Fatimid Caliphate. Its architectural features such as its massive stonework, pointed arch, and defensive recesses demonstrate early Islamic military planning and urban boundary marking [16]. During the Ayyubid and Mamluk periods, the gate underwent restorations and adaptations, reflecting the continuity of use and the layered history of Cairo's fortifications. As a rare surviving element of this military infrastructure, Bab al-Barqiyya offers critical insight into the intersection of architecture, power, and urban morphology in Islamic Cairo [17]. Location of Bab Al- Barqiyaa is shown in **Fig. 7**, **Fig. 8**, & **Fig. 9**.

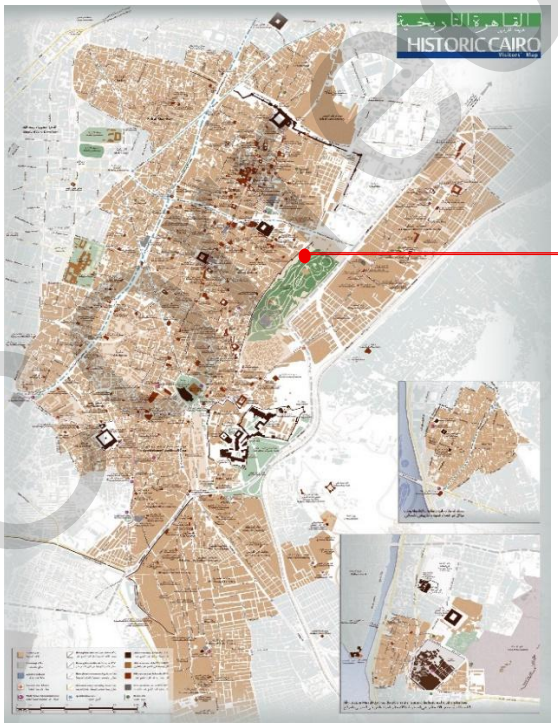


Fig. 7: Historic Cairo Map

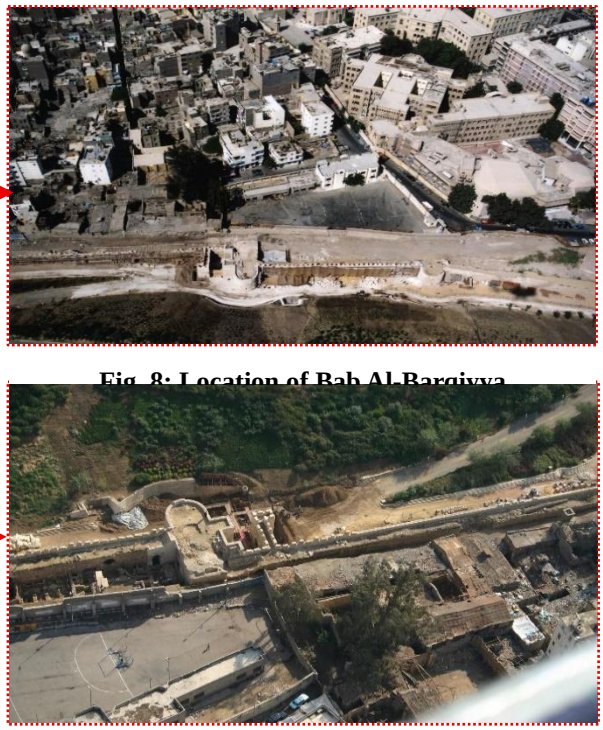


Fig. 9: Bab Al-Barqiyya

3.4 Objectives from the Analytical Study

The primary objective of the analytical study is to evaluate the effectiveness of accessible digital documentation techniques specifically photogrammetry and 3D modeling in assessing the material and structural condition of historic architectural sites. By analyzing and comparing digital models of Bab al-Barqiyya and Bab al-Nasr, the study aims to identify visible forms of deterioration such as surface erosion, material loss, deformation, and structural instability.

3.5 Case Study details

The historic wall measures over 1500 metres in length, running north from Bab al-Wazir to al-Azhar Street, and forms the boundary between the Darb al-Ahmar district of Historic Cairo and the new Park. Following preliminary investigations, the Aga Khan Trust for Culture (AKTC) began restoration works in 2000. Most of the work along the side facing the Park was completed in 2008. The gate, constructed from stone as shown in **Fig. 10**, features an intricate layout characteristic of medieval Middle Eastern fortified gates, commonly referred to as a "bent entrance." Instead of allowing direct passage through a straight opening in the wall, the design requires movement through two right-angle turns, diverting traffic sideways as it enters and exits. This architectural strategy was meant to slow down advancing forces and make direct attacks more difficult. Today, Bab al-Barqiyya stands as a critical case study for architectural conservation and digital heritage documentation, particularly in the context of photogrammetry and LiDAR-based 3D modeling, due to its historical layers and partially reconstructed condition [16]. All information about Bab al Barqiyya is summarized in **Table 2**.

Table 2: Case study information

Project Details	
Project Name	Bab al-Barqiyya
Location	Burg al-Zafar Street, Cairo, Egypt
Style	Fatimid
Built during	Between 1176 and early 13th century
Renovated	2000-2008

Fig. 10: Bab Al-Barqiyya

3.6 Digital tools used in the Documentation

As a part of the Aga Khan Trust for Culture project, here are digital tools used in the restoration of Bab al-Barqiyya (2000–2007):

a) Photogrammetry: Used to generate accurate 3D visualizations of the gate's architectural form from photographs and provided a spatial basis for identifying deformation, missing stones, and areas of erosion [18]**.**
b) Point Cloud Analysis: Image-based point clouds were generated to analyze surface conditions and it provided high-precision data for stone-by-stone mapping, especially for irregular surfaces [19], as shown in **Fig.11**.
c) Digital Visualization: Rendered visualizations and models were shared with the public and stakeholders to enhance public engagement with the heritage site [20], as shown in **Fig. 12**.

Fig. 11: cloud of points, computer rendering created by photogrammetry

Fig. 12: 3D Model of Bab Al-Barqiyya

3.7 Contribution of digital methods in the documentation of Bab al-Barqiyya

Digital methods contributed to material condition assessment and structural analysis in the restoration of Bab al-Barqiyya as the following:

a) Material Condition Assessment

- High-resolution photogrammetry was employed to capture detailed surface textures and stone conditions. This allowed conservation experts to identify erosion patterns, surface decay, and loss of stone details without physically interfering with the structure. Furthermore, the digital imagery enabled visual comparison between pre-restoration and post-restoration states, enhancing monitoring and planning [11], as shown in **Fig. 13** & **Fig. 14**.

Fig. 13: loss of stone details before restoration

Fig. 14: the wall after restoration

- Point cloud density mapping highlighted inconsistencies in the façade and helped detect gaps, voids, or non-original insertions within the masonry [21]. as shown in **Fig. 15** and **Fig. 16**, where the green color indicates stable, flat, horizontal zones such as roofs, upper walls, or stable ground, while yellow to orange areas indicate rising/falling terrain, might correspond to steps, slopes, or subsiding ground levels. Red Areas indicate lowest points or significant structural voids, may be areas of loss or erosion or collapsed stonework [22].

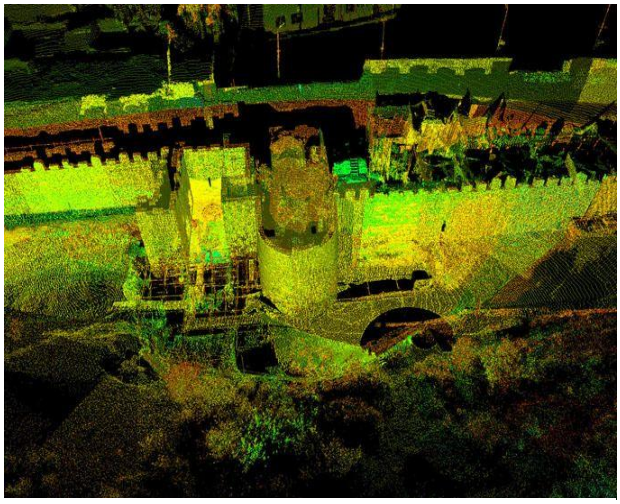


Fig. 15: point cloud map of the wall

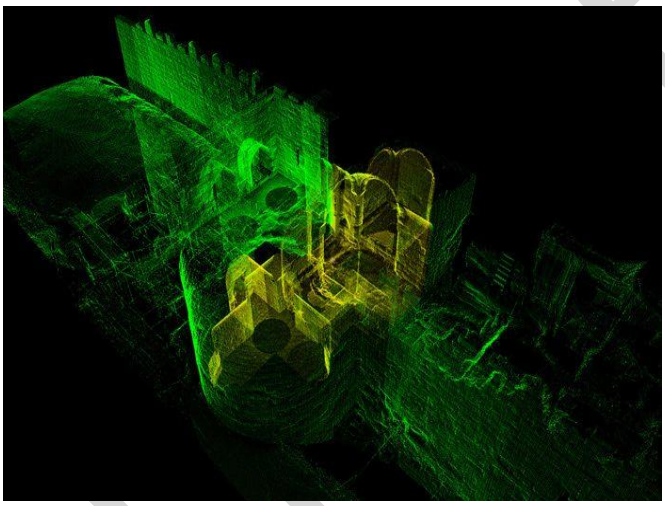


Fig. 16: point cloud map for the gate

a) Structural Analysis

- Digital elevation models and section views were generated from 3D scans to study the gate's geometry. These tools enabled experts to evaluate whether structural deformation had occurred over time, especially in arches and vaults [1], as clarified in **Fig.17**.

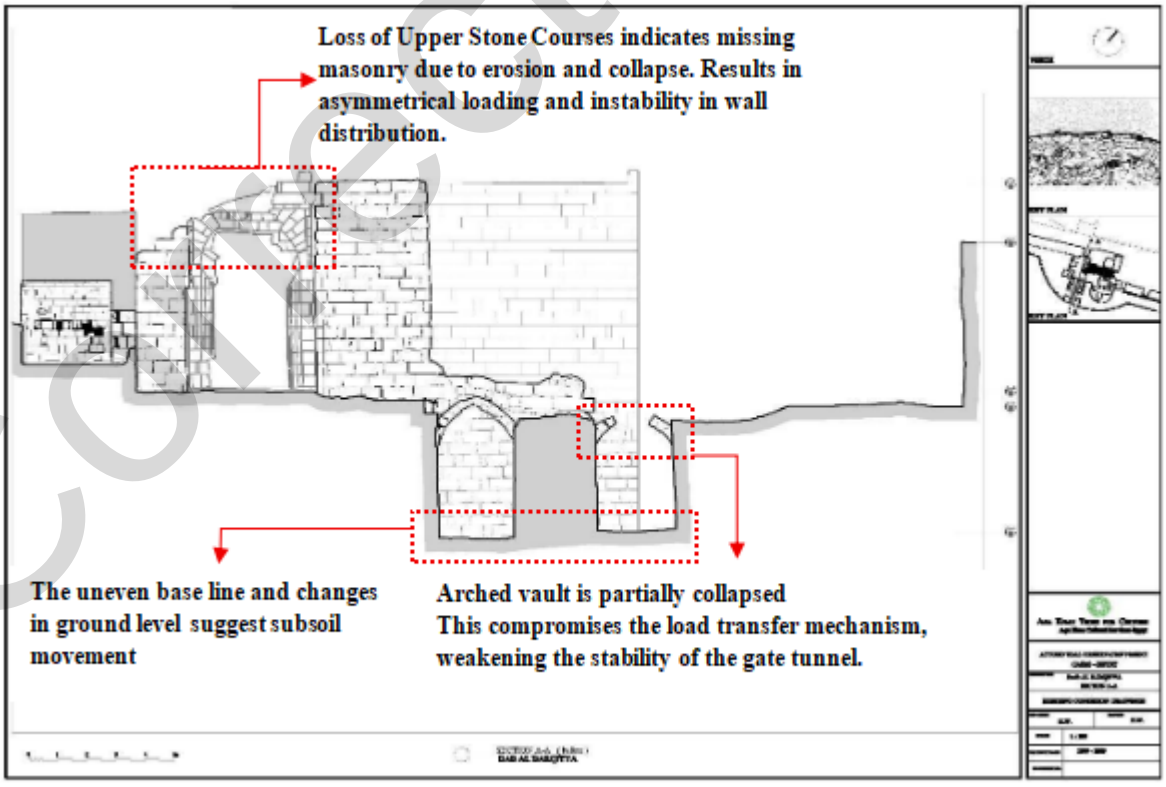


Fig. 17 :Cross section for the existing condition

All contributions of digital methods in restoration of Bab Al-Barqiyya is summarized in **Table 3**.

Table 3: Contribution of digital methods in restoration of Bab Al-Barqiyya

Aspect	Digital Method Used	Contribution
Surface decay detection	Photogrammetry	• Detailed surface textures and stone conditions. • Identified erosion.
Missing stone tracking	Point Clouds Map	Located voids and displaced elements.
Structural deformation	Elevation modeling, section analysis	Revealed shifts, arch distortions

4. APPLIED STUDY

The applied study aims to implement a streamlined and accessible methodology for the digital documentation of historic structures, building upon the conservation model exemplified in the restoration of Bab al-Barqiyya. To assess the transferability and effectiveness of this workflow, the same documentation process will be applied to a second heritage site in Cairo which is Bab al-Nasr.

The procedure begins with the systematic acquisition of high-resolution digital photographs taken from multiple, overlapping angles around the target structure. These images processed using Polycam, an open-source photogrammetry mobile application, to generate a three-dimensional textured mesh. The resulting 3D model analyzed using tools which is CloudCompare, where outputs including elevation maps, profile sections, and point cloud density assessments generated.

These visual outputs serve as diagnostic indicators to detect physical irregularities, surface degradation, or structural deformation. The analysis will be guided by the same criteria applied to the Bab al-Barqiyya dataset, allowing for a comparative evaluation between the two case studies. This approach seeks to demonstrate the feasibility of employing simplified digital workflows for the documentation and preliminary assessment of urban heritage sites, particularly in resource-limited contexts.

4.1 Application on Bab Al-Nasr

Bab al-Nasr is one of the three remaining gates of the Fatimid walls of Cairo. Built in 1087 by Badr al-Jamali, the powerful vizier of the Fatimid Caliph al-Mustansir, the gate served as a northern entrance to the fortified city and a key military outpost.

Designed as a military structure as shown in **Fig.18**, the gate features two massive rectangular flanking towers, a central arched passage, and intricate decorative elements including shield motifs and Kufic inscriptions carved in limestone. Its defensive architecture reflects the Fatimid strategy

of incorporating bent entrances and machicolations to resist direct assaults. Over the centuries, Bab al-Nasr underwent several conservation efforts, including early 20th-century restorations by the Comité de Conservation des Monuments de l'Art Arabe and more recent interventions by Egypt's Supreme Council of Antiquities. Today, it stands as a well-preserved example of Fatimid military architecture and forms a key part of the Historic Cairo UNESCO World Heritage Site [23]. All information about Bab Al-Nasr is summarized in **Table 4**.

Table 4: Bad Al-Nasr Details

Project Details	
Project Name	Bab al-Nasr
Location	Al-Gamalyya Street, Cairo, Egypt
Style	Fatimid
Built during	1087
Renovated	20th-century

Fig. 18: Bab Al-Nasr

5.1.1 DSLR camera (high resolution) photos

High-resolution DSLR images as shown in **Table 5** are used in Meshroom significantly, which improves the quality and accuracy of 3D photogrammetry models. The detailed imagery enables more precise feature detection and matching, leading to better camera alignment and finer mesh reconstruction. Additionally, DSLR cameras offer superior color fidelity, sharpness, and control over lighting and focus, which enhances texture mapping and model realism. These advantages make DSLR images particularly valuable for documenting architectural heritage with high fidelity and minimal preprocessing.

Table 5: DSLR photos

DSLR photos

5.1.2 Using Polycam mobile application to Process the images (for photogrammetry and 3D model generation)

The photogrammetric model of Bab al-Nasr, was generated using Polycam, a mobile-based 3D scanning application that employs Structure-from-Motion (SfM) and Multi-View Stereo (MVS) algorithms. High-resolution images were captured around the monument using a smartphone camera under consistent lighting conditions to ensure optimal texture mapping and geometric accuracy. These overlapping images were processed directly within the app, where feature matching and triangulation techniques were applied to reconstruct the 3D geometry of the gate, as shown in **Fig. 19**. The result was a textured mesh model as shown in **Fig. 20**, exported in .glb format, representing the architectural features and façade of the gate. Although some geometric distortions were present primarily due to limited access to higher and lateral viewpoints, the model successfully documented key elements such as the arched entrance, stone reliefs, and battlements.

Fig. 19: photogrammetry from Polycam

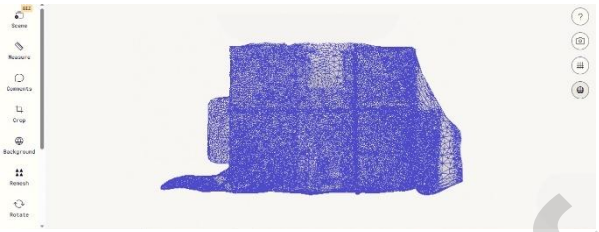


Fig. 20: Mesh from Polycam

5.1.3 Import the resulting 3D geometry into CloudCompare (to produce elevation maps, cross-sections) and to Autodesk ReCap (to determine the status of the materials and structure).

The photogrammetric documentation of the historic gate produced two complementary outputs: a high-resolution textured mesh and a dense point cloud. The textured mesh, exported in .obj format with applied RGB textures, was primarily utilized for visual inspection and material assessment in Autodesk ReCap. It contained approximately 980,000 vertices and provided an accurate geometric representation with an average spatial error of ±1.2 cm. This enabled a detailed evaluation of the structure's current condition, particularly in identifying surface deterioration and material inconsistencies.

In parallel, the dense point cloud, exported in .ply format and consisting of approximately 1.3 million points, was processed in CloudCompare for analytical purposes. It facilitated the generation of cross-sections and elevation profiles through interval slicing, using a fixed spacing of 1 meter. The inclusion of RGB values per point enhanced the interpretability of the model for heritage specialists, aiding in the integration of visual and geometric data.

Overall, the results demonstrate that the photogrammetric workflow provided both geometric precision and visual richness, making it suitable for heritage recording, conservation planning, and comparative analysis over time.

All the technical specifications of the of the generated 3D model is shown in **Table 6**.

Table 6: Technical Specifications of the of the Generated 3D Model

Parameter	Value / Method
Cloud Density	~1,300,000 points (high-density photogrammetric capture from Polycam)
Distance Calculation	Point-to-plane Euclidean distance (CloudCompare: Cloud-to-Mesh algorithm)
Error (Average Deviation)	±1.2 cm (mean distance between the point cloud and fitted surface)
Interval Distance	1 meter (cross-sections and elevation slices extracted at 1 m vertical intervals)

Importing a 3D model into CloudCompare and Autodesk ReCap helps in several important analysis, processing, and visualization tasks, especially in 3D documentation.

Elevation and cross-sections analysis

Digital methods contributed to material condition assessment and structural analysis in the restoration of Bab al-Nasr as the following:

- **Material condition assessment**

The stone façade of Bab al-Nasr displays multiple signs of material degradation and historical wear. Most prominently, there is significant discoloration and patching across the elevation indicating stone replacement, salt damage, or moisture-related erosion. The lower zones of both towers reveal darkening and staining, likely from rising damp or urban pollution as clarified in (Figure 21). Red color indicates areas of loss or erosion, while the stone blocks near ground level appear more eroded and uneven, which may be attributed to capillary moisture action or vehicular vibration from the adjacent road. Furthermore, multiple open joints and cracks are visible between blocks in certain areas, particularly around the archway and upper battlements posing structural concerns, as clarified in (Figure 22) due to thermal expansion over time.

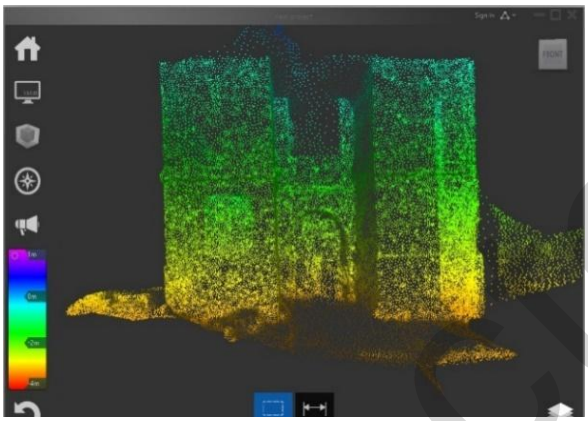


Fig. 21: Model in Autodesk ReCap

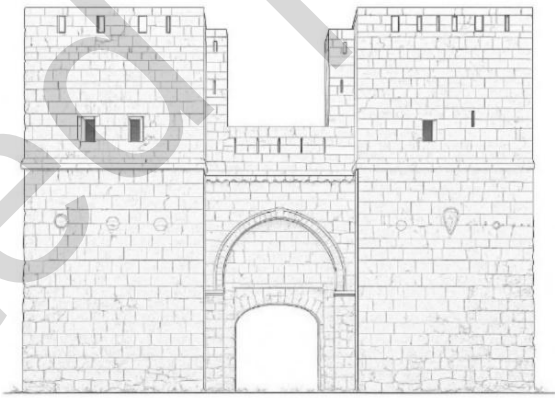


Fig. 22: Elevation used in Material Analysis

- **Structural analysis**

Fig. 23 presents a scalar field visualization superimposed on a section diagram of Bab al-Nasr, highlighting areas of potential structural deterioration. Scalar fields in this context are used to represent variations in surface displacement, curvature, or deformation detected from the 3D model data. The color gradient ranging from blue (indicating minimal deviation) to red (indicating higher deviation) reflects surface irregularities and structural stress. The red-dashed rectangles identify critical zones such as the vertical joint, parapet, and lower wall sections, where noticeable anomalies appear. These variations may correspond to cracks, differential settlement, or material degradation, which were also observed in visual inspections.

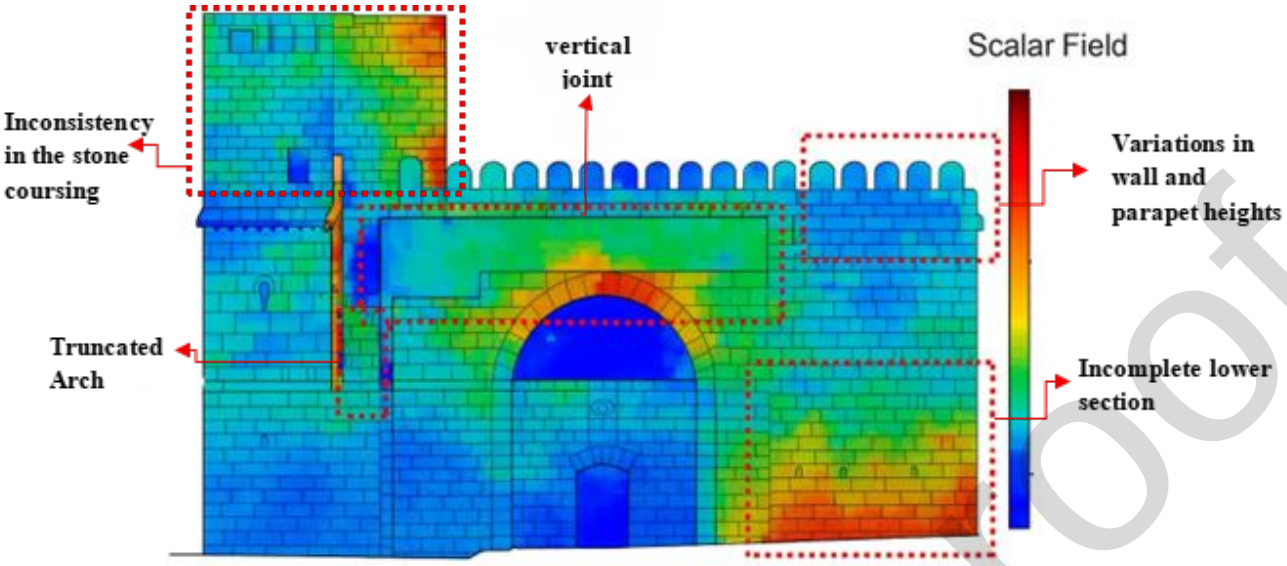


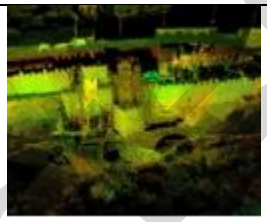
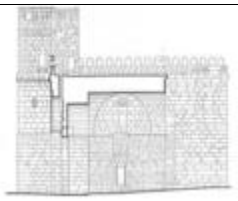
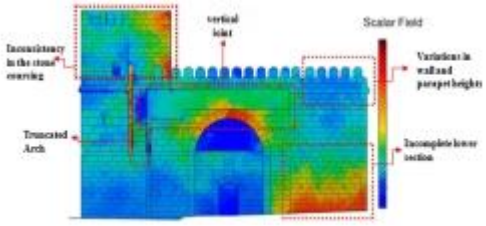
Fig. 23: Section used in Structural Analysis

Material and structural analysis performed through Claudcompare and Autodesk ReCap generated images are summarized as shown in **Table 7**:

Table 7: Material and structure analysis

Problem	Type	Notes
Stone erosion	Material	accelerated by environment
Joint cracking	Structure	Possible early signs of settlement
Rising damp	Material/Stucture	lead to deep deterioration
Loss of decorative details	Material	Irreversible unless restored
Incompatible restorations	Material	May introduce long-term risks

Table 8: Summary of the comparative analysis

Comparative analysis of two Fatimid-era gates		
	Bab al-Barqiyya	**Bab al-Nasr**
Picture		
Location	Burg al-Zafar Street, Cairo, Egypt	Al-Gamalyya Street, Cairo, Egypt
Style	Fatimid	Fatimid
Built during	1087	Between 1176 and early 13th century
Digital tools used in the Documentation	Photogrammetry and 3D of the gate 	Polycam application for photogrammetry and 3D of the gate
	Point cloud 	Point Cloud by Autodesk Recap
	Elevations and sections 	CloudCompare for elevations and sections 
Contribution of digital methods in the documentation	a) Material Condition Assessment ▪ Non-original insertions within the masonry. ▪ Erosion patterns, surface decay, and loss of stone details	b) Material Condition Assessment ▪ significant discoloration and patching ▪ The lower zones of both towers reveal darkening and staining. ▪ multiple open joints and cracks
	Structural Analysis	Structural Analysis 

CONCLUSIONS

This study explored the practical application of digital documentation techniques within the field of urban heritage conservation in Cairo, focusing on two prominent historical gates: Bab al-Barqiyya and Bab al-Nasr. By employing accessible photogrammetry tools and open-source platforms, the research aimed to assess both the technical viability and the broader potential of low-cost digital workflows in supporting heritage preservation efforts.

At Bab al-Barqiyya, the use of photogrammetry and point cloud analysis, as conducted through the Aga Khan Trust for Culture, demonstrated the ability of digital methods to capture intricate architectural details, detect structural irregularities, and provide data essential for informed conservation planning. In contrast, Bab al-Nasr served as a test site for a simplified workflow using tools such as Polycam and CloudCompare. This case showed that even non-specialists can successfully generate accurate 3D models capable of supporting basic condition assessments, highlighting the democratizing potential of such methods.

The study underscores the value of open-source software in making heritage documentation more inclusive and replicable. The ease of access and affordability of tools like Polycam and CloudCompare make them particularly suitable for academic institutions, student-led projects, and community-based initiatives. This opens new pathways for grassroots engagement in heritage protection, fostering wider participation from local actors who may not have access to high-end equipment or technical expertise.

Despite its limitations in comparison to high-precision technologies such as terrestrial laser scanning (TLS) or AI-driven platforms, photogrammetry proved to be a reliable alternative, especially for preliminary analysis and early-stage documentation. The models generated in this study achieved a spatial accuracy of approximately ±1.2 cm sufficient for visual analysis, condition monitoring, and informing conservation strategies. Furthermore, the digital outputs were not limited to visual representation but served as valuable tools for technical assessment, enabling the identification of material loss, geometric irregularities, and potential structural deformation.

Overall, this research reinforces the idea that digital heritage documentation need not rely on expensive or complex systems to be impactful. Instead, accessible and cost-effective technologies can empower a more proactive and preventive approach to heritage conservation. By allowing for early detection of deterioration and facilitating informed maintenance planning, such workflows contribute meaningfully to long-term preservation goals. The findings advocate for scaling digital documentation efforts across other sites in Cairo and similar heritage-rich cities, enabling broader inclusion of communities, students, and professionals in safeguarding cultural landmarks.

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CONFLICT OF INTEREST

The authors have no financial interest to declare in relation to the content of this article.

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