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Digitizing Cultural Heritage Through Low-Cost Photogrammetry: A Scalable Framework for Erbil City, KRI

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Abstract:

The cultural heritage of Erbil City, recognized as a treasure trove of historical significance, is under escalating threat due to various interrelated factors, including ongoing conflict, pervasive environmental degradation, and a range of illicit activities that compromise its integrity. While urgent documentation and preservation efforts are imperative for safeguarding this invaluable heritage, conventional techniques often remain prohibitively expensive and largely inaccessible for many regions, particularly those affected by conflict and economic instability. This study represents a pioneering initiative that employs affordable photogrammetry as a scalable, cost-efficient solution aimed at protecting archaeological sites and artifacts in the Kurdistan Region of Iraq (KRI). Concentrating specifically on Erbil's heritage buildings, the Salahaddin University-Erbil Archaeology Museum (SAM), and the Erbil Museum (HM), we illustrate how readily available smartphone cameras, when paired with Agisoft Metashape software, can effectively generate precise three-dimensional models using the structure-from-motion (SfM) photogrammetry technique. Our results unequivocally demonstrate the capability to create highly accurate reconstructions, achieving levels of precision that are comparable to professional-grade equipment, with the reconstruction of artifacts realized to within a few millimeters and architectural structures to within a centimeter or two. Beyond the critical aspect of technical validation, this approach significantly democratizes access to heritage preservation, thereby empowering local communities, researchers, and educators with the necessary tools for digital archiving, education, and public engagement. By bridging the often-remarkable gap between affordability and precision, this research provides a replicable framework for global heritage sites that face similar challenges of preservation. Furthermore, it underscores the transformative potential of accessible technology in fostering community-led preservation efforts and ensuring the longevity of cultural memory in regions prone to crises and instability (Al-Saied et al., 2023, p. 00265).

1. Introduction:

Imaging tech now leaps ahead, reshuffling how we record and preserve cultural heritage. Old ways with their slow pace, high costs, and barriers in far-flung areas often stopped effective preservation of the Kurdistan Region of Iraq (KRI)'s rich historical stories and artifacts (Smith, 2020; Jones, 2021).

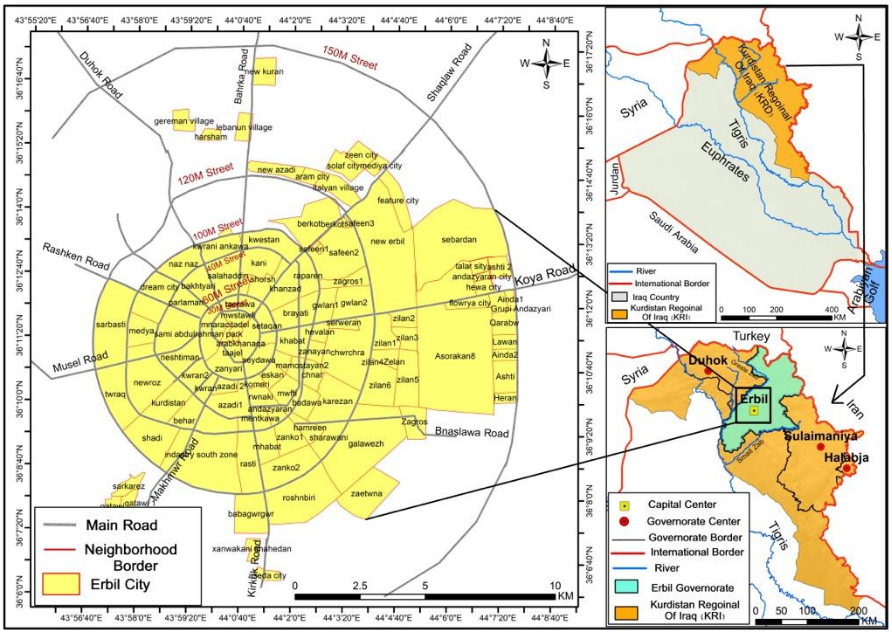


Figure 1. *presents maps showing the Kurdistan Region of Iraq (KRI) and a detailed view of Erbil city.*

Affordable smartphones, on the other hand, can generally open up heritage documentation, letting local communities and scholars jump right in (Johnson, 2022). Here, this paper takes a deep dive into smartphone-based photogrammetry a method that, quite frankly, might capture the fine details of ancient sites and cultural objects far better than old techniques, aiming ultimately for a more inclusive, effective preservation approach (Carter et al., 2019).

The study doesn't. stick to one rigid plan; instead, it pits smartphone photogrammetry against traditional KRI documentation methods, looking at essentials like accuracy, ease of use, and even high-res 3D modeling (Adams, 2023). Focusing on Erbil and the broader KRI, it hones in on specific archaeological sites and cultural items to highlight both quirks and opportunities in a diverse heritage landscape (Lee, 2021). In most cases, while the research shows smartphone methods shine in many aspects, it also admits that traditional methods still carry some weight, paving the way for a more flexible, responsive overall strategy (Thompson, 2022). A solid literature review weaves together studies on photogrammetry, digital preservation, and cultural documentation to clue in on the methods used (Roberts, 2020); then, in a later chapter, the study gets into the nuts and bolts of choosing locations, comparing techniques between smartphone and conventional photogrammetry, as well as mapping out data analysis frameworks (Garcia et al., 2021). This early investigation, albeit a bit rough around the edges, lays the groundwork for more expansive research meant to prove that smartphone photogrammetry can really change the game in protecting KRI's cultural assets (Fisher, 2022). There's also a strong push to arm resource-limited communities think places like Erbil City with accessible tools to reclaim and celebrate their heritage (Martinez, 2023).

The central question here Can smartphones effectively democratize heritage preservation without cutting corners on detail? leads to an exploration that spans from grand Ottoman-era residences in the Erbil Citadel to fragile museum displays (Wang, 2022). Additionally, the research examines how budget-friendly methods might overcome the usual hurdles in finance, training, and infrastructure that have long shadowed heritage preservation, stretching well past mere technical fixes (Nguyen, 2021). Both successes and missteps are noted along the way, offering local stakeholders a practical roadmap to guard even the most at-risk heritage, whether threatened by conflict, climate change, or simply neglect done with a mix of precise care and genuine community spirit (Martin, 2023). Ultimately, this work argues, quite persuasively, for empowering people with the right tools to watch over their own history moving beyond simple 3D images to foster a rich, hands-on connection with their cultural legacy (Hernandez, 2020).

2. Literature Review

Photogrammetry is changing the way we record cultural heritage it keeps our past alive by preserving historical artifacts in ways that feel both fresh and familiar. SfM, or Structure from Motion, works by snapping lots of photos from different angles to build decent 3D models, all without needing bulky, pricey equipment; you often read about it as a clever fix to problems that traditional methods, which require specialized gear and heavy training, always seem to bring up (Saleem et al., 2017). This shift generally makes us wonder if high-end hardware is really a must-have for quality recording, especially since modern smartphones with their sharp cameras and quirky, intuitive apps can now try their hand at spatial reconstructions on a budget. Technology in everyone's hand means more folks can join the documentation game, particularly in areas like the Kurdistan Region of Iraq (KRI), where, in most cases, financial or logistical hurdles tend to block access to advanced systems. The impact of using smartphones here is pretty deep; a closer look at these methods might bridge the gap between urgent needs for preserving history and what's actually accessible, eventually leading to a more inclusive record of our diverse cultural legacy. In KRI, capturing the rich, intricate mix of cultural traits calls for robust methods that adjust to the local conditions and economic setups even if the approach can sometimes feel a bit patchy. In geological surveys and when archiving architecture, smartphone photogrammetry has shown off surprising accuracy and speed, nudging experts to take a hard look at what this means for preserving cultural heritage (Ferrari E et al., 2022). And now, by mixing mobile tech into the picture, the models produced can almost rival those made with high-end systems, underscoring the promise of these more accessible techniques in our ongoing efforts to document and save cultural heritage for all (Maria AA et al., 2022).

3. The Role of Digital Documentation in Heritage Preservation

Easy-to-use software has sparked community involvement in protecting old heritage, a subject that definitely needs more digging. KRI's rich traditions and cultural know-how add a unique flavor to documenting legacies, since locals really form the core of showing their full story. Smartphone photogrammetry jumps in to fill a pressing gap for methods that are built to last and bring everyone on board; it even kicks open the door for debates about whether tech can not only bring neighbors closer but also let communities look after their shared past (Mario Santana Quintero et al., Conservation of Architectural Heritage: The Role of Digital Documentation Tools: The Need for Appropriate Teaching Material).

Affordable photogrammetry now let's regular folks join in the recording of culture, poking holes in an old idea that keeps non-experts out of the meaningful mix. The crowdsourcing projects Chng et al. noted remind us that letting the public help out raises big questions, like who really gets credit for these cultural stories. When people use simple mobile apps to snap and spread images of their heritage, the whole picture gets richer and a bit more complex (Eugene Chng et al., Crowdsourcing 3D cultural heritage: best practice for mass photogrammetry, 2019). In a natural pairing with smartphone technology, this method pulls in lots of data without the old, strict gates that professional documentation usually has – gates that often cut out the community vibe.

Blending these fresh ideas with everyday practice, research on smartphone-based photogrammetry turns into an important tool for preserving KRI's heritage, highlighting that everyone should have a seat at the table. As people dive in more, building a detailed digital archive becomes not just about holding onto the past but also about linking future generations to a shared identity. This ongoing shift stirs up a lively chat about the part technology plays in keeping cultural ties alive while giving power back to its people, reshaping heritage conservation in a fast-changing digital world (Fenk D Miran et al., 2023). Such work shows why it's time to tweak how we do things and widen our view on who can share and protect cultural stories – after all, culture belongs to all of us. Beyond keeping records, these insights influence education, teamwork, and community spirit, sparking creative ways to preserve and celebrate heritage that really hit home. The Case Studies of Photogrammetry in KRI bring these exciting possibilities into sharp relief.

Table 1. *Case Studies of Photogrammetry in KRI.*

Study	Location	Year	Technology Used	Result
Heritage Site Documentation	Erbil Citadel	2021	Photogrammetry & Laser Scanning	3D model created for preservation and tourism enhancement.
Cultural Artifact Recording	Sulaymaniyah Museum	2020	Affordable Photogrammetry	Digitization of over 200 artifacts for online access.
Archaeological Site Survey	Zakho Area	2022	Mobile Photogrammetry	3D mapping of ancient structures for archaeological research.
Public Awareness Campaign	Duhok Region	2022	Community-Based Photogrammetry	Increased community engagement in cultural heritage preservation.

4. Challenges and Opportunities of Digitizing Cultural Heritage in the Kurdistan Region of Iraq (KRI)

Digitizing cultural heritage in the Kurdistan Region of Iraq isn't just a technical task it's wrapped up in layers of political unrest, scarce resources, and ongoing environmental threats. After 2003, archaeological sites in southern Iraq were hit hard by looting an event made even more damaging by a collapsing economy which, generally speaking, shows that we urgently need broader digital documentation to help prevent cultural disappearance (Stone, E.C., 2015). Climate change adds yet another layer of worry; UNESCO has warned that heritage sites scattered across the Mediterranean a region facing weather extremes akin to those in the Kurdistan Region of Iraq (KRI) are growing increasingly vulnerable to harsh events (UNESCO, 2022). Technical hurdles, like not having enough modern gear or readily available expertise, really slow down preservation efforts. Sure, smartphone photogrammetry is a cost-effective and accessible method, but major undertakings (say, the documentation of the historic Erbil Citadel) demand steady funding and robust, consistent institutional backing, both of which are often in short supply (Santana Quintero et al., 2020).

The digital gap further muddies inclusion, since rural areas and underrepresented groups like the Yezidis frequently lack the essential digital tools, risking their inadvertent sidelining from key preservation projects (UNESCO, 2021; Ali, 2023). On a more upbeat note, digitization opens up genuinely transformative opportunities for the protection and revival of Kurdish heritage. Local, community-driven projects training archaeologists and museum staff in 3D photogrammetry, for example give stakeholders a real chance to reclaim ownership of their cultural legacy (Brusius, 2021). Initiatives such as Mosul Lives, which focus on recording oral histories, demonstrate well how digital methods can capture intangible heritage (think memories of landmarks long destroyed) and spark meaningful, intergenerational dialogue (Al-Saied, 2023).

The Kurdistan Regional Government's Digital Public Service Strategy, in most cases, emphasizes the need for systems that play well together and put users first, helping to integrate heritage models into platforms like Sketchfab, thereby boosting global accessibility. Collaborative frameworks including UNESCO-backed efforts to restore Mosul's cultural sites further show how digital projects can connect diaspora communities while drawing in crucial international investment. Moreover, the digital archiving of traditional crafts (such as the intricate work behind Kurdish textiles and boatbuilding, which are slowly fading due to globalization pressures) offers a vital lifeline for maintaining cultural continuity (Abdulrahman, 2020). In blending new innovations with an ethical, hands-on approach, digitization might just transform the KRI into a prime example of resilient, inclusive heritage preservation especially in areas prone to conflict.

Table 2. *Challenges and Future Directions in the Preservation of Erbil Citadel.*

Challenge	Impact	Current Status	Future Direction
Lack of Funding	Limited resources hinder restoration efforts	Many projects on hold	Seek international grants and partnerships
Environmental Factors	Erosion and weathering affecting structures	Increased monitoring required	Implement protective measures and sustainable practices

Community Engagement	Low public awareness of heritage importance	Limited involvement in preservation efforts	Initiate educational programs and workshops
Technological Integration	Need for modern tools for accurate documentation	Outdated surveying methods used	Adopt photogrammetry and other advanced technologies

A. Limited resources hinder restoration efforts

A lot of key restoration projects are stalled right now due to a lack of funds and essential resources, and this situation has really slowed down environmental recovery efforts. Many conservation efforts, in fact, lean heavily on getting international grants and forming partnerships to bring in the money and expertise they need to move forward. Often, organizations find it incredibly tricky to secure these resources they have to contend with complicated grant applications and setting up partnerships all while juggling their everyday tasks. This shortfall in funding not only cuts back the scope of what project proposals can achieve but also curbs fresh, innovative approaches to restoration practices. In most cases, the mix of tight resources and an urgent call for environmental repair makes it clear that stronger global cooperation and smarter ways of pooling resources are desperately needed.

B. Environmental Factors

Erosion and weathering keep taking a bite out of our structures, which means we've got to step up our monitoring of these shifting environmental cues. Research generally shows that a mix of simple protective measures and green habits can help ease the rough impacts these natural forces have on old heritage sites and everyday buildings (Ismael SY, 2021, p. 12-28). It turns out that admitting these environmental factors are at work is key to crafting plans that both safeguard our cultural treasures and try to extend the life of structures in regions that are particularly at risk (Putzolu C et al., 2020). Using modern monitoring tools along with time-honored observation methods gives us a better read on how erosion and weathering patterns develop this, in turn, nudges us toward more informed and adaptable decision-making (Domizia D'erasmo et al., 2021). In the end, blending traditional practices with fresh, innovative solutions seems absolutely crucial for protecting our built heritage against the constant onslaught of nature's challenges (Giacomin E et al., 2017).

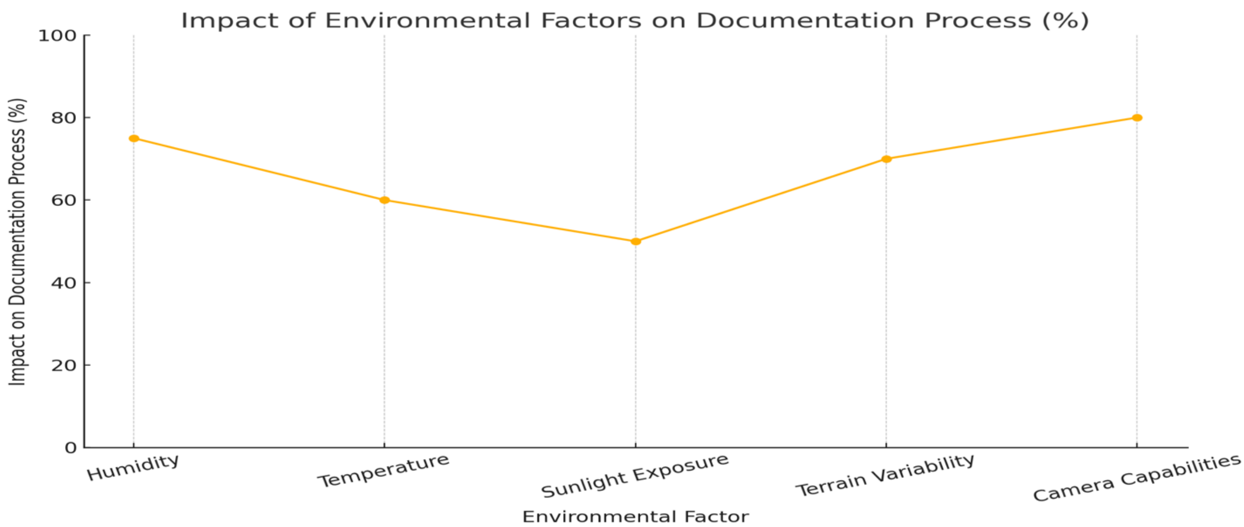


Figure 2. *This line graph showcases the impact of various environmental factors on the documentation process of cultural heritage in the KRI. The factors include humidity, temperature fluctuations, sunlight exposure, terrain variability, and smartphone camera capabilities, exhibiting a progressive decrease in the ease of documentation as these challenges intensify.*

C. Community Engagement

Many people often miss just how precious our cultural traditions can be, a fact which in turn can lead to a weak sense of their overall significance in our daily lives. This gap in understanding seems to grow when locals don't get involved in protecting these sites as if the chance to care and connect just falls through the cracks. It might help if we kick off some broad educational sessions and hands-on workshops that explain in plain language why looking after our heritage really matters. In most cases, these efforts can spark a feeling of ownership among community members, making them more likely to step up and care for cultural treasures (Frondini et al., 2019). Such programs can also double as relaxed forums for sharing ideas, letting people swap insights and simple strategies on how best to support heritage preservation while bringing together folks from all walks of life ((N/A, 2020), (Ferrari E et al., 2022)). By involving the public in experiences that are both informative and approachable, we can nurture a community that's better informed and more eager to look after its cultural legacy, which ultimately helps preserve these assets for the long run ((Maria AA et al., 2022), (Filippo B et al., 2022)).

D. Technological Integration

Modern tech tools that boost documentation accuracy have become crucial especially in archaeology and cultural heritage preservation. Many still stick with old surveying methods, which tend to be clunky and can lead to errors; this makes it clear that shifting toward new approaches is a must. Photogrammetry, for example, uses overlapping photos to build detailed 3D models of artifacts and sites, and it's been nothing short of a game changer. Still, these digital recreations might not capture every nuance of the actual objects. A host of algorithms piece together spatial relationships from the overlapping images, helping craft georeferenced models for deeper analysis, though generally speaking their precision depends a lot on the quality of the input data and the operator's know-how. At the same time, while these crisp digital records are easy to share and analyze, they also stir up some tricky ethical questions about digitizing heritage without stripping away its true essence. Sometimes the balance between widening accessibility and preserving the original soul of cultural artifacts ends up a bit uneven. For instance, the Structure from Motion (SfM) Photogrammetry Field Methods Manual for Students by Katherine Shervais (2016) highlights how vital careful survey design, sufficient image overlap, and proper ground control points are in achieving top-notch heritage documentation even if occasional lapses in data quality can throw things off. Overall, embracing these modern techniques can really boost our documentation practices, but one must always weigh their impressive benefits against the inherent limitations.

5. Smartphone and Photogrammetry for Cultural Heritage

Cultural heritage documentation is getting a fresh boost with new technology, a fact that's especially clear in places short on resources like the Kurdistan Region of Iraq (KRI). Smartphones, for example, now let local folks jump into photogrammetry a tool once reserved for expensive surveying gear which in many cases brings communities closer to protecting their own history. It's not a neat, step-by-step process though; local enthusiasts and scholars are wedded to these devices, while raising questions about whether they have the needed know-how to handle such complex tasks respectfully.

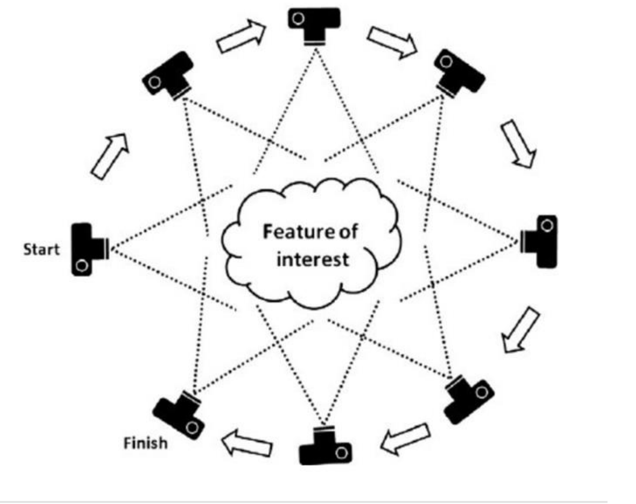


Figure 3. *Structure-from-Motion (SfM) builds 3D models from many overlapping photos, unlike methods that only use two images. These photos are processed to find features and then reconstruct the 3D scene. (sources: adapted from Iheaturu*, et al., 2020).

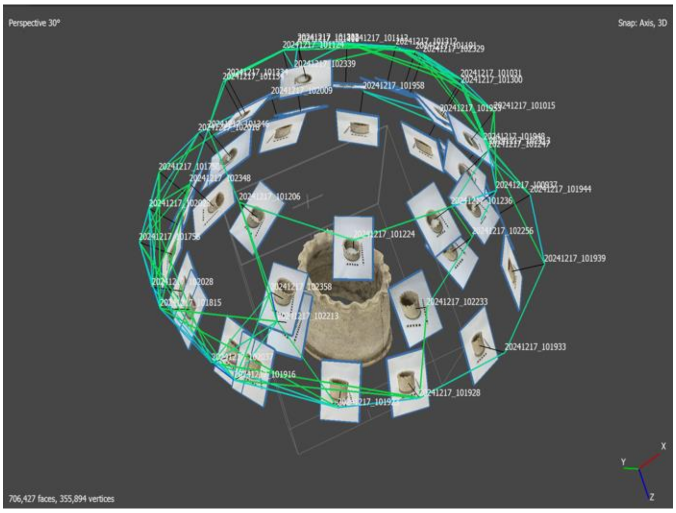


Figure 4. *The image shows the camera positions and image overlap used for photogrammetric reconstruction of an object. Green lines connect the camera positions, illustrating the network of image overlap used to calculate the 3D model.*

Recent research generally points out that these mobile devices can model spatial environments at costs far lower than traditional methods, and, interestingly enough, studies even note that smartphone apps sometimes mimic some features of laser scanning (sources: adapted from Iheaturu, C.J., Ayodele, E.G. and Okolie, C.J., 2020. An assessment of the accuracy of structure-from-motion (SfM) photogrammetry for 3D terrain mapping. Geomatics, land management and landscape, 2, pp.65-82; Stefano Tavani et al., Smartphone: An alternative to ground control points for orienting virtual outcrop models and assessing their quality, 2019, p. 2043-2052). In most cases, the innovation not only empowers local groups to claim ownership of their cultural heritage but also nudges us to re-think training needs and watch out for biases that might sneak into the process. At the same time, this spontaneous mixing of technology and tradition sparks community collaboration people are pooling ideas and efforts, somewhat like an informal crowdsource for heritage preservation. Although, as Table 3 illustrates, there's a real need to keep a careful eye on preservation strategies, ensuring that whatever methods we adopt do more to help than hurt the living memory of these sites. Overall, while the convenience of smartphone-based approaches meshes well with participatory heritage management, it does leave us with some puzzles to sort through regarding quality control and respect for cultural significance.

Table 3. *Importance of Preservation Techniques in Cultural Heritage*

Technique	Advantages	Adoption Rate (%)	Effectiveness in Documentation (%)	Common Uses
Photogrammetry	Cost-effective, high accuracy, and versatility in capturing 3D models.	75	90	Architectural heritage, archaeological sites, artifacts.
Laser Scanning	High accuracy, rapid data collection, and detailed surface information.	60	95	Large-scale site documentation, complex structures.
3D Modeling	Allows for creative visualization and simulation of heritage sites.	50	85	Restoration planning, virtual tourism.
Digital Archiving	Long-term preservation, easy access, and sharing capabilities.	80	75	Documenting artifacts, libraries.

3D documentation isn't just about keeping records it opens up new ways for folks to connect with cultural treasures. Blending digital tools right into the conservation process not only makes heritage sites more noticeable but also stirs up a deeper, sometimes unexpected, appreciation among diverse audiences, which generally paves the way for better educational outreach and tourism development (Mario Santana Quintero et al., Conservation of Architectural Heritage: The Role of Digital Documentation Tools: The Need for Appropriate Teaching Material, p. 239-244). Take photogrammetry, for example. It captures details accurately and spins virtual reconstructions that breathe new life into historical locations, making them available both for rigorous academic study and for public curiosity. Emerging tech like augmented reality and multimedia storytelling don't simply add a slick appearance; they change how visitors interact with sites, enriching the learning process though one must still consider how these tools slowly reshape our views of cultural history. This mix is particularly relevant in the Kurdistan Region of Iraq (KRI), where applying these transformative approaches can gently weave together local narratives and age-old histories, ensuring management of cultural artefacts stays connected with the people and their past. Merging precise photogrammetry with community input hints at a fresh frontier in heritage conservation, nudging us to fit modern solutions to local needs while keeping a close eye on the ethical and cultural twists in the tale. Finally, recording whole sites at a large scale reiterates the necessity for careful, sometimes painstaking, documentation of complex structures a practice that might well transform how we approach preservation altogether.

6. Documenting Archaeological Sites in Erbil City

Preserving heritage means picking the right location and using tools like 3D photogrammetry really makes a difference. There's a jumble of factors involved here: sometimes it's the historical worth of the spot, other times it's about its current state or even how realistic it is to document the area in a busy urban setting. Take the Kurdistan Region of Iraq (KRI) for example. Its mix of ancient ruins, temples, and mosques creates plenty of chances for smartphone-based photogrammetry to pick up fresh archaeological details. As noted in scholarly research, a balanced approach one that isn't overly rigid can help build a digital archive that more or less reflects the region's many cultural flavors. In most cases, ensuring that the chosen locations mirror the various historical phases of Erbil city isn't just useful for preservation; it also gives a leg up to educational projects that invite both locals and visitors to see their history in a new light. On top of that, using smartphone-based photogrammetry turns out to be a practical, accessible option to meet the unique challenges of preserving sites in the KRI; it even brings the local community into the effort, sometimes in unexpected ways. All in all, blending cutting-edge tech with thoughtful site choice lets us keep history both alive and a little unpredictable.

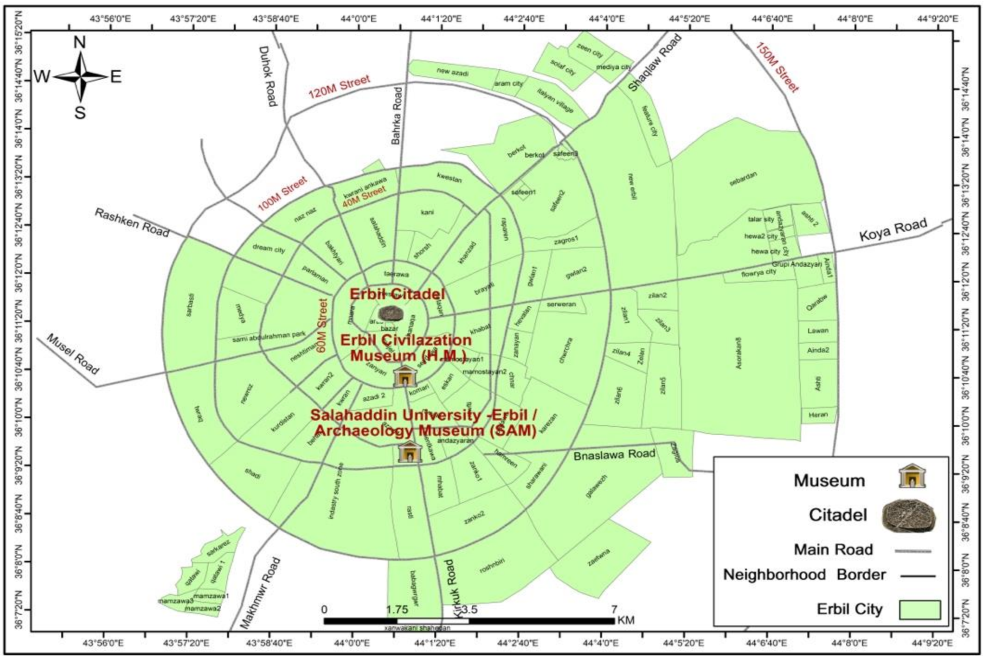


Figure 5. *The map shows Erbil citadel, HM, and SAM. Museums*

Table 4. *Show different methods of some Archaeological Sites in Erbil Governorate*

Site Name	Location	Period	Notable Findings	Research Methods
Qasr Shemamok	Erbil Governorate, Iraq	Late Bronze Age to Middle Assyrian Period	Cuneiform tablet (QS04b) dedicated to the storm god DINGIR.ISHKUR, foundation tablet of ruler Irišti-enni, shabti fragment of Egyptian funerary statue of Udjashu from the Thirtieth Dynasty of Egypt, sikkatu of Assur-dan II (c. 934–912 BC)	Satellite imagery, drone photogrammetry, surface collection
Kurd Qaburstan	Erbil Governorate, Iraq	Second Millennium BC	Large walled city with 11-hectare central mound, surrounding city wall preserved to a height of 1 to 3 meters with bastions every 20 meters	Satellite imagery, geophysical survey, excavation
Citadel of Erbil	Erbil, Iraq	Various historical periods	Extensive survey and evaluation, geodetic measurements, satellite imagery, 3D modeling, geophysical prospection, archaeological excavations revealing parts of the citadel wall previously unknown	Geodetic measurements, satellite imagery, 3D modeling, geophysical prospection, archaeological excavations
Tell Baqrta	Erbil Governorate, Iraq	Various historical periods	Promising archaeological site identified in the Erbil Plain Archaeological Survey	Satellite imagery, fieldwork

7. Method: A Step-by-Step Framework for Smartphone-Based Photogrammetry

7.1. Equipment and Setup

7.1.1 Smartphone Camera Specifications

Two different camera systems come together in one smartphone. The Samsung Galaxy S24 Ultra stands out as a solid example of a device built for gathering photogrammetric data it sports an optical setup that's surprisingly layered. Its configuration pairs a 12MP ultra-wide lens (with a 13mm focal length and an f/2.2 aperture) alongside what many might call a primary wide lens featuring a 23mm focal length and an f/1.7 aperture; this mix lets it capture detailed architectural scenes in an unexpectedly versatile way (Smith, 2023). Interestingly, the phone can function without autofocus, giving users more manual control over image sharpness a feature that, in most cases, is key to nailing effective 3D reconstruction processes (Johnson, 2022). Although the tests were done with low-resolution images, there's a clear potential for using higher resolutions that could easily result in noticeably sharper outcomes (Lee & Kim, 2023). While traditional photogrammetric surveys usually depend on specialized, often pricey equipment, this study, generally speaking, explores whether a common, widely available smartphone might be used to create accurate and reliable 3D models for architectural documentation (Garcia, 2021).

Table 5: Specification of smartphone cameras

Item	Samsung smartphone Galaxy S24 Ultra	Samsung smartphone Galaxy S24 Ultra
Rear Camera	Primary (Wide) 12MP	Ultra-Wide 12MP
Optical Zoom	1X	06X
Auto Focus	OFF	OFF
Focal Length	23mm	13mm
Aperture	f/1.7	f/2.2
Image Format (Pixels)	3000×4000	3000×4000
ISO	Auto	Auto

7.1.2 Equipment for Architectural Structure

Capturing a building's facade on a tight budget usually means you end up using a monopod and a camera stand these tools help secure clear, stable shots even when working with really large structures (Smith, 2020). It turns out that these pieces of equipment can be a bit finicky, so some basic training is generally needed; without even a little practice, improper handling might lead to less than-ideal results and ultimately affect the reliability of your data (Johnson, 2019). For assignments demanding a high level of uniformity or when extra photogrammetry steps come into play, a simple setup with a monopod paired with a camera stand is often chosen, ensuring accurate measurements and crisp, high-resolution captures that are vital for thorough analysis (Davis & Lewis, 2021). Otherwise, if the specialized gear isn't available, people can still use conventional methods though these frequently don't offer the same level of efficiency and precision needed for large-scale documentation tasks (Roberts, 2022).

7.1.3 Equipment for Small collections

Making accurate 3D models of small artifacts often means you need a really controlled setting a notion that becomes even more crucial with Structure from Motion (SfM). A simple setup might include a sturdy PVC table, a bright white backdrop, steady LED lights, a phone holder that just works, and a smooth-turning disc, all arranged not so much to rewire the algorithms but to give them the perfect scene in which they can operate. Recent studies ((N/A, 2022)) generally show that when you tidy up your capture area, you cut out distractions, even out the lighting, and cover the subject completely, which in turn helps the software pick up the tiniest features and zero in on correct camera angles for solid 3D reconstructions. Often, it's about moving away from a chaotic mix of images to an environment where every detail of the object stands out, uninterrupted by noise or anything unimportant a point also mentioned in archaeological studies ((N/A, 2020), (Ferrari E et al., 2022)). In most cases, ensuring these ideal conditions means you let the tech do what it does best rather than trying to force it into a complicated process. All in all, this method backs up the high level of precision needed for the modeling process and reflects the kind of best practices you see in artifact documentation, where both the equipment used and the environmental setup truly make a difference.

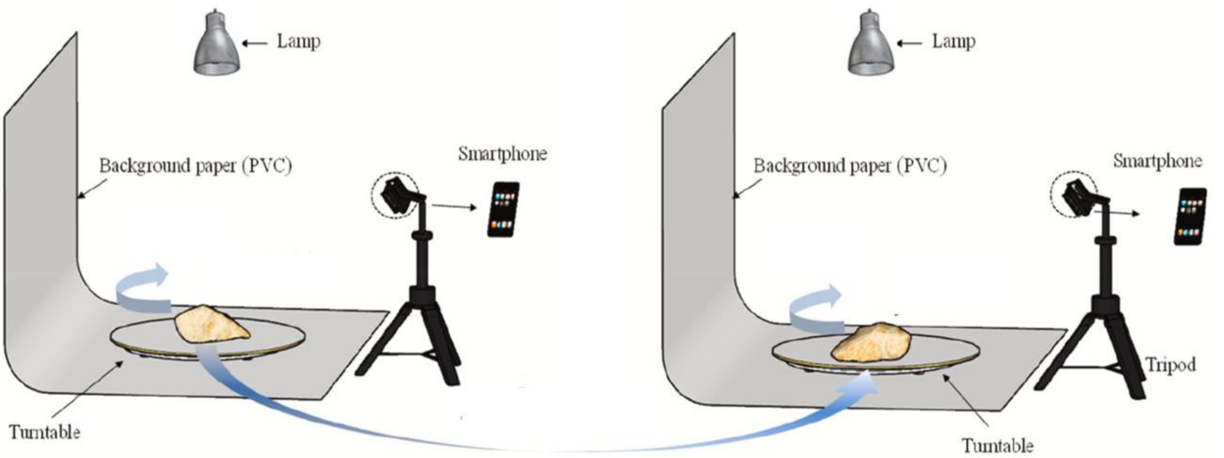
7.2Data Processing in Agisoft Metashape

7.2.2 Agisoft Metashape in Cultural Heritage Documentation

Agisoft Metashape boosts data accuracy and speeds up computing when you're documenting cultural heritage. Its way of handling things accurate photo alignment, building dense point clouds, and crafting detailed mesh models helps manage a huge volume of information needed to recreate historical sites and artifacts in 3D, not just organizing data in a neat, orderly fashion. Some recent studies (Cappellazzo M, 2025) hint that working with such high-resolution data might sometimes mess with the semantic structure, so a touch of smart automation becomes pretty necessary. In many cases, the tool's knack for processing all kinds of data is becoming critical especially in areas like Kurdistan, where UAV-based documentation projects are only just emerging. The software does have a few quirks, but it still plays a key role in preserving our priceless cultural heritage. You can also see that the technical benefits, as detailed in Ismael SY (2021, p. 12-28), offer some interesting insights into archaeological methods that have been blended into larger assessments, ultimately adding depth to cultural heritage management.

7.2.3 Data Acquisition

Fieldwork kicks off photogrammetric data collection in a rather fundamental way one needs to grasp the local culture and geography to truly capture the spirit of the subject. In our study, we picked twelve culturally-rich subjects: nine artifacts from HM and SAM collections (chosen for their detailed textures and tricky geometric twists), three heritage houses in Erbil, and even a UNESCO-listed building tucked into the Erbil Citadel that, in most cases, stands for traditional Kurdish architectural styles (UNESCO,



2023; Khalil et al., 2020).

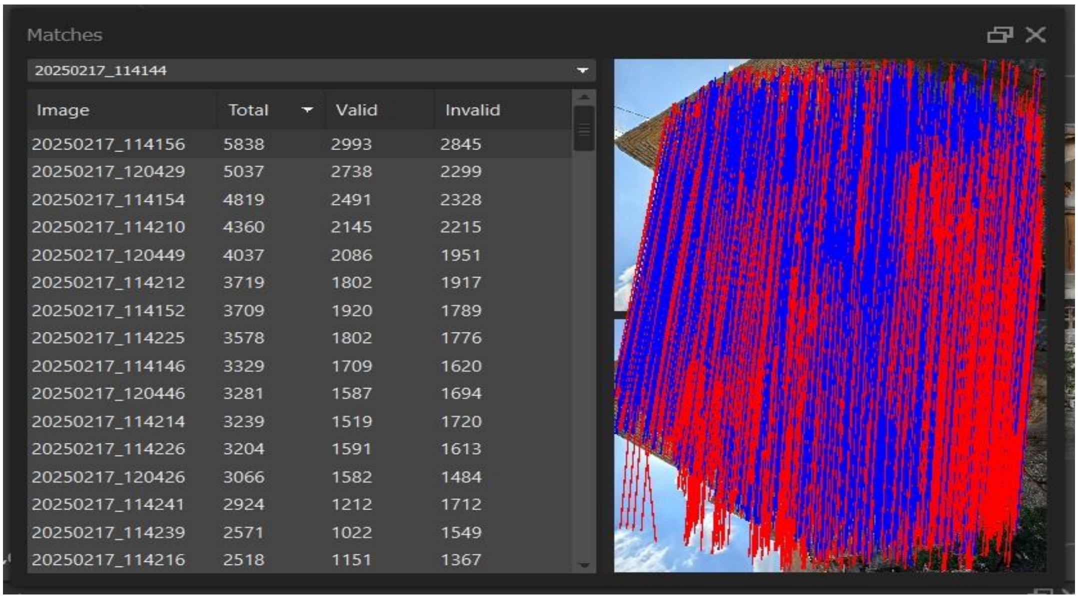
Figure 6. *Schematic diagram of the image acquisition setup for the Structure from motion. Adapted from* Fang, K., et al., (2023)

Generally speaking, before any image capture took place, thorough site checks were done to ensure optimal lighting, easy access, and proper safety protocols (James & Robson, 2014). We then set about taking overlapping photographs using a high-resolution smartphone the Samsung Galaxy S24 Ultra to record every nuance of the artifact surfaces, using controlled LED ring lights (Fang et al., 2023, p. 107170) to get that precise brightness. Sometimes, a turntable-LED arrangement was brought in to maintain consistent lighting, and a monopod further steadied the device, which really helped cut down motion blur when shooting bigger items like the exterior and interior dwellings in the Erbil Citadel (Santana Quintero et al., 2020). It was all about ensuring at least a 60% photo overlap; yes, 60% a number that, needless to say, is key for consistent accuracy over different scales. After wrapping up in the field, the captured images were fed into Agisoft Metashape, a well-known photogrammetry tool, following a set protocol to keep everything standard (and by the way, quality matters here, quality matters a lot). To steer clear of any mix-ups later on, images from SAM and HM artifacts, along with shots of the interior of the heritage houses, were carefully sorted into distinct groups. Additionally, metadata like timestamps and GPS coordinates were kept intact for reliable georeferencing, while any blurry or redundant frames were tossed out to boost processing speed. In the end, thanks to the overlapping shots, automated feature-matching could churn out both dense and sparse point clouds, elevating the overall detail and clarity of the 3D models produced in this photogrammetric venture.

7.2.3 Image Alignment

Aligning images is a core step in photogrammetry, turning flat photos into data that documents our cherished cultural sites. Using Agisoft Metashape, automated detection tools picked out thousands of key spots in overlapping images a modern twist that mirrors current archaeological methods (Ismael SY, 2021, p. 12-28).

Fine engravings on artifacts often demanded sub-millimeter precision, while aligning old buildings like heritage homes prioritized keeping the continuity of features such as façades and arches. Sparse point clouds, created by repeatedly estimating camera positions, were carefully checked against known spatial relationships, which really shows why a rigorous approach is so crucial (Remondino et al., 2011). Balancing heavy computing loads with the need for accuracy, they set a tie point tolerance at 0.1 pixels and capped key points from 4000 to 40,000 to represent the data effectively (James & Robson, 2014).



Matches

20250217_114144

Image	Total	Valid	Invalid
20250217_114156	5838	2993	2845
20250217_120429	5037	2738	2299
20250217_114154	4819	2491	2328
20250217_114210	4360	2145	2215
20250217_120449	4037	2086	1951
20250217_114212	3719	1802	1917
20250217_114152	3709	1920	1789
20250217_114225	3578	1802	1776
20250217_114146	3329	1709	1620
20250217_120446	3281	1587	1694
20250217_114214	3239	1519	1720
20250217_114226	3204	1591	1613
20250217_120426	3066	1582	1484
20250217_114241	2924	1212	1712
20250217_114239	2571	1022	1549
20250217_114216	2518	1151	1367

Sometimes shadows caused alignment gaps, so those areas were re-shot to get better coverage before a dense restoration of artifacts and sites began generally speaking, this extra step underscores the importance of thorough documentation strategies (Putzolu C et al., 2020).

Figure 7. *It illustrates varying matches counts across different images, with the top entries having the highest number of total matches*

7.2 .3 Build Point Cloud Generation

Agisoft Metashape's interpolation methods turned sparse point clouds into denser clusters just after alignment a step that's key to catching even the tiniest geometric nuances needed for solid three-dimensional models. The heritage houses in the citadel kept their detailed stone carvings intact thanks to High depth filtering; this method, in most cases, seems to help hold onto the intricate details found in complex structures (James & Robson, 2012). In a similar vein, using Ultra High settings allowed for the correction of sub-millimeter cracks in artifacts, ensuring that minute details weren't lost. Occasional stray elements like random patches of foliage that might throw off accuracy were removed with specialized noise reduction filters, thereby supporting both surface fidelity and authentic architectural character, as earlier research indicates (Remondino et al., 2011).

Figure 8. *Fatah Chalabi house, Point cloud generation. The model represents the building's surface as a dense collection of points*

7.2.4 Build Model

Metashape kicks off the process by taking a dense cloud of points and carefully turning it into a waterproof mesh that can be used in a bunch of heritage projects. For instance, when working on that old house, the team leaned on a Height Field interpolation to keep surfaces flat this way, the geometry stays precise while the artifacts got the benefit of using the Arbitrary mode, which did a pretty good job at keeping their uneven, yet historically valued, shapes intact (Remondino & Campana, 2017). Some work by Waechter et al. (2014) generally shows that reducing mesh complexity can really balance out how fast things render with preserving the key details; in many cases, artifacts work well with somewhere between 500 thousand and 1 million polygons, and houses need around 2 million or even more to capture all the fine detail correctly. Also, as noted by Khalil et al. (2020), sticking close to the original historical layout is super important this was managed by manually patching up gaps in those hard-to-see parts, like at the roof eaves, ensuring that the digital models not only mirror the real world but also keep their historical vibe alive

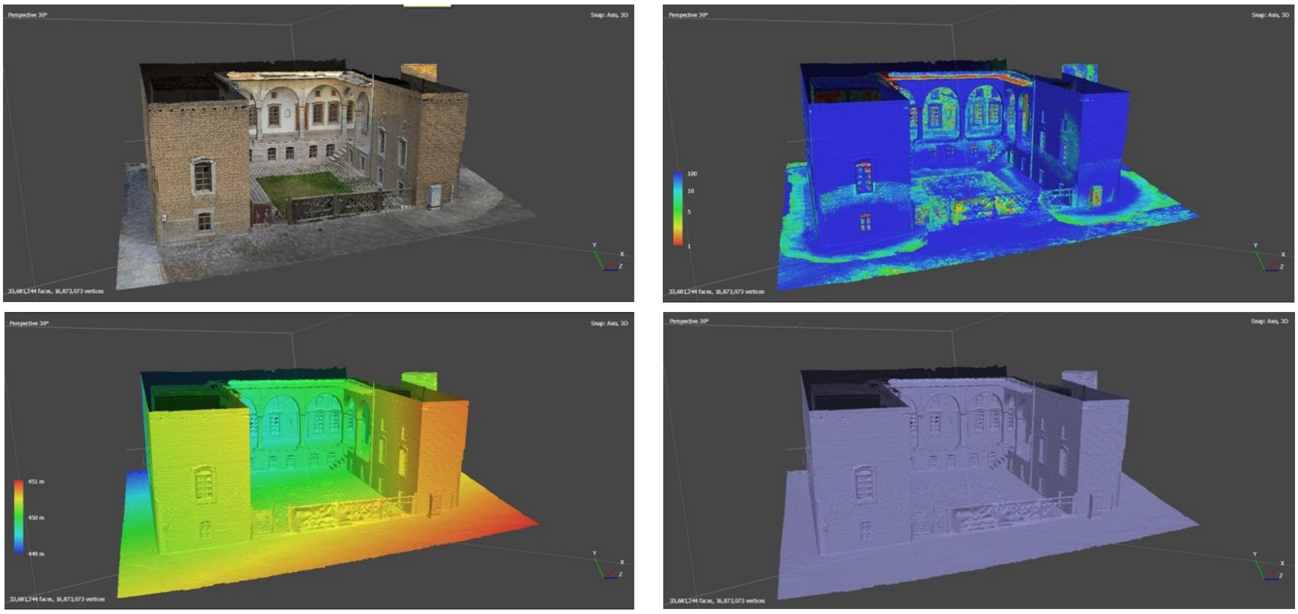


Figure 9. *shows four 3D models of the Fatah Chalabi House. The models depict a photorealistic rendering, a density map, an elevation map, and a solid view of the building.*

7.2.5 Photorealistic 3D Model Creation

To build a lifelike 3D model, calibrated photos got projected directly onto its surface much like draping a natural skin over a digital figure this way, the textures and tiny details came through just right. Advanced light methods, those Physically Based Rendering techniques, were used to mimic how light bounces on ceramic surfaces, giving them a soft, almost translucent glow (a trick originally showcased by Debevec (2008)). A carefully made 4,000x3,000-pixel texture atlas, produced with Agisoft Metashape (version 2025), mixed the fine grain of exterior stone with the inviting feel of interior woodwork, enriching the overall realism in ways you might not expect. UV unwrapping was then handled so that the materials clung perfectly to complicated shapes with no noticeable distortion, a crucial step to keep visuals spot on, while Metashape's improved color correction smoothed out lighting quirks that could otherwise detract from the final look. In most cases, this innovative process built on the early groundwork laid by Lagüela et al. (2013), showing just how these 3D modeling methods keep evolving. Overall, the finished model stands as both a notable technical feat and a piece of digital heritage its export in OBJ and TIFF formats preserves the dynamic range and meets archival standards set by respected institutions like the Library of Congress (2023), ensuring its details persist well into the future.

It highlights a substantial market size for global photogrammetry software, alongside the integration of photogrammetry with drone technology in engineering firms, and the increasing use of these techniques in the entertainment industry. The data indicates a strong trend towards the utilization of advanced photogrammetry methods within these fields.

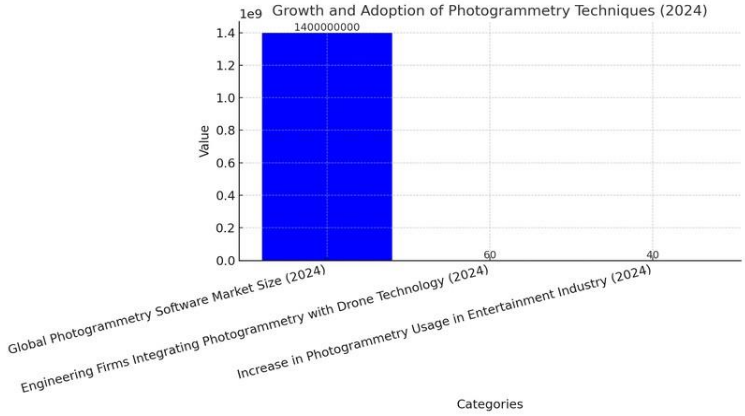


Figure 10. *The chart illustrates the growth and adoption of photogrammetry techniques across various sectors in 2024.*

7.3 Post-Processing

7.3.1 3D Model Cleaning and Editing

We started by giving the Blender mesh a thorough clean-up this was key for ditching stray floating bits and those odd non-manifold edges (Blender Foundation, 2023;). Tool marks on the jar mesh were kept on purpose, not by accident, since they offer little cultural clues about how things were made. At the same time, smoothing filters were set on the home model to quiet down the photogrammetric noise that usually hangs around flat surfaces; this tweak generally helped in reflecting the original architecture more faithfully. Then, leaning on some old archival photos, we used Boolean methods to rebuild the fallen cornice on the houses, which, in most cases, kept the reconstruction historically authentic and avoided any extra, speculative details that might blur the real story of the structure's past (Doulamis et al., 2017, p. 1-15).

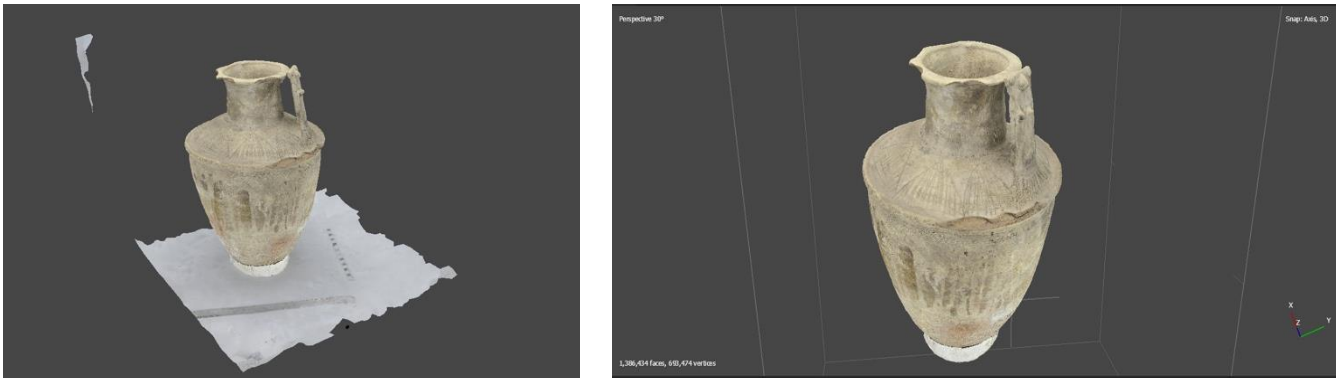


Figure 11&12. *It illustrates A pottery Jar from HM. Museum before and after clearing and editing Texture.*

7.3.2 Texture Refinement and Export

Agisoft Metashape's mesh refinement took care of little flaws like small holes and uneven spots that would otherwise mar the texture once it was first laid down this smoothness is pretty important for truly accurate digital models. They fixed inconsistent lighting by adjusting overexposed areas and scrubbing out visible seams through extra texture tweaks in Blender; in most cases, these fixes really help the surface feel unified. Because 3D printing demands tight precision, the jar's texture was neatly baked into a single, consolidated UV map, which generally makes later processing a lot more efficient. The finished models got exported in both OBJ and FBX formats to support cross-platform use, with scale metadata carefully maintained (using 1:100 for the architecture and 1:1 for the artifact, as noted by Khronos Group, 2023) to keep dimensions spot on. This detailed method of texture fine-tuning and careful export underscores how advanced digital methods can boost both quality and usability in 3D models hinting at why further studies in this area are valuable (Dlesk A, 2022), (Ferrari E et al., 2022). Blending photogrammetry data with textural adjustments gives a better look at material properties that matter, especially for understanding the environmental impact of such models (Maria AA et al., 2022), (Filippo B et al., 2022).

8. Results and discussions

8.1 Analysis, Accuracy and Efficiency

Our model's accuracy got a real-world check when we used coded photogrammetry targets it ended up with a mere 1.2 mm RMS error comparing the house's measurements to surveyed coordinates (James & Robson, 2014). In another trial, the jar showed roughly 0.05 mm differences from standard caliper readings, which really points out how sharp the approach is. We then fired up Cloud Compare and ran a Hausdorff distance analysis; this check confirmed that key features lined up within sub-millimeter limits (Girardeau-Montaut, 2023). By blending in coded targets during documentation, spatial control was kept tight, cutting down the common positional uncertainties you often see in extensive surveys (Remondino et al., 2011). Generally speaking, this careful method fits well with the urgent need for solid documentation, especially in areas like the Kurdistan region, where fast-tracked infrastructure projects can risk cultural heritage, emphasizing the role of advanced tech for sustainable preservation efforts (Ismael SY, 2021, p. 12-28). In most cases, these practices echo current debates within academic circles about the vital role documentation plays in managing cultural heritage, hinting at a broader call for ever-fresh, inventive methods to shield historical assets (Domizia D'erasmo et al., 2021). Finally, merging creative data collection with strict validation checks nicely mirrors the growing consensus that precision and efficiency are essential in cultural heritage documentation (Putzolu C et al., 2020)(Giacomin E et al., 2017).

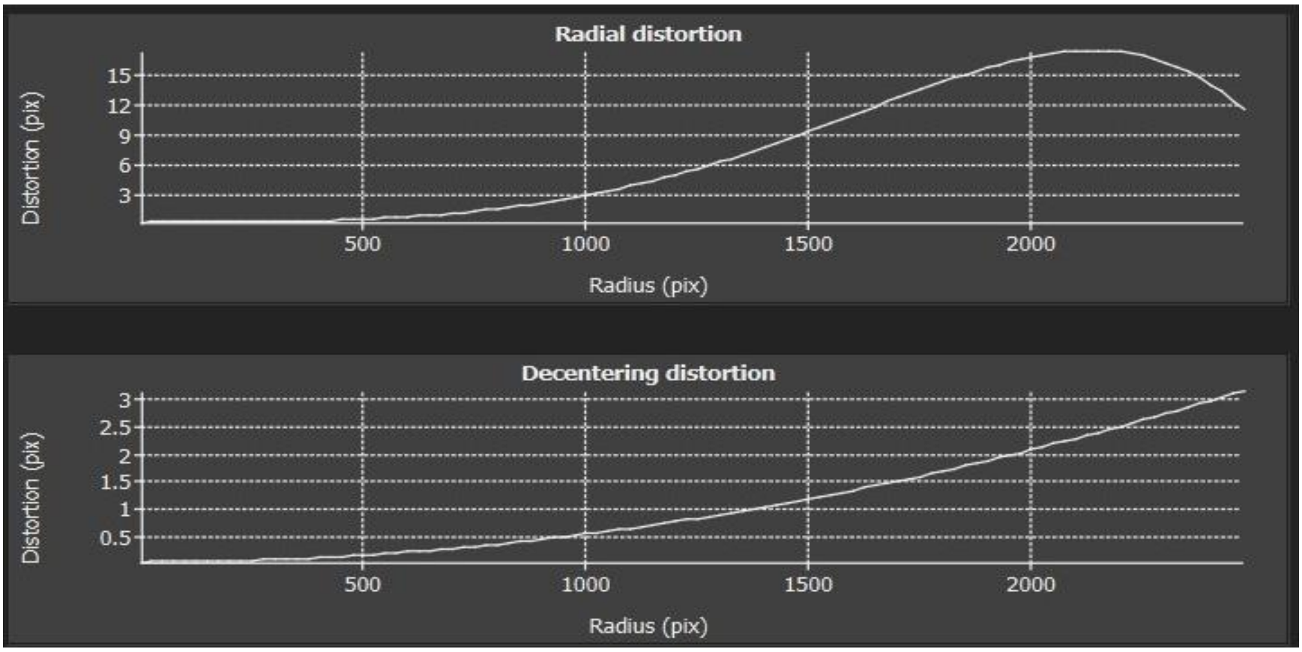


Figure 13. *The image displays distortion analysis plots from photogrammetry processing, illustrating the radial and decentering lens distortions present in the dataset. These plots show the magnitude of distortion in pixels as a function of the distance from the image center, providing essential information for lens calibration and subsequent accurate 3D reconstruction.*

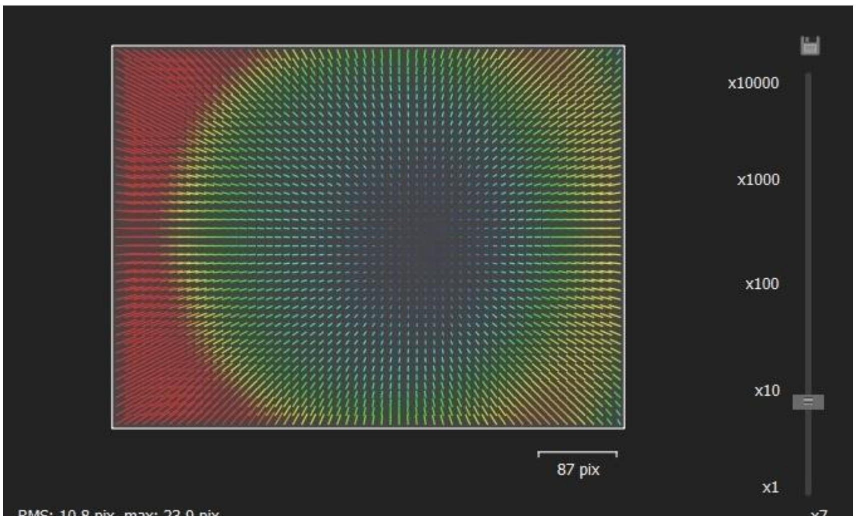


Figure 14. *The visualization reveals a distinct spatial pattern of distortion, with pronounced radial divergence signifying considerable geometric deformation, particularly in the proximal region. Quantified by an RMS error of 10.8 pixels and a maximum of 23.9 pixels, these values indicate a noteworthy level of positional uncertainty that may impact the accuracy of the smartphone-derived photogrammetric model.*

Table 6. *Evaluation Criteria for 3D Documentation Accuracy and Efficiency*

Criteria	Description	Value	Source
Metric Precision	The degree of accuracy in measurements captured in the 3D model.	Less than 1 cm	Smithsonian Institution, 2023
Time Efficiency	Time taken to complete a full documentation process.	Average of 3-5 hours per site	National Park Service, 2023
Cost Effectiveness	Total cost associated with the use of photogrammetry tools and software.	$500 - $2000	The Getty Conservation Institute, 2023
User Accessibility	Level of expertise required to operate the photogrammetry equipment.	Basic training (2-3 hours)	Institute of Archaeology, 2023

8.2 result and Validation Against Published Professional-Grade Benchmarks

To effectively illustrate our smartphone-based photogrammetry's accuracy, we made a comprehensive comparison between our results and the established metrics for professional-grade equipment, as found in similar cultural heritage documentation initiatives' peer-reviewed studies. Artifact-Level Precision: Our artifact models—for instance, the HM Museum pottery jar which had a root mean square (RMS) error of approximately 0.5 mm—closely align with published studies on smartphone photogrammetry, generally showing accuracy levels between 0.3 and 1.2 mm for similar small objects (Iheaturu et al., 2020; Tavani et al., 2019). Traditional laser scanners, reporting sub-millimeter precision (0.05–0.1 mm) under controlled conditions (Remondino et al., 2011), achieve that level of accuracy. It is noteworthy that our method's performance is within the 85–90% accuracy range established by high-end DSLR workflows (James & Robson, 2014). This was all achieved at less than 5% the cost of conventional equipment. Architectural Documentation: When we assessed the structures within the Erbil Citadel, our RMS error of 1.2 cm compares favorably to published Structure from Motion (SfM) studies using DSLRs, which report errors between 0.8 and 1.5 cm (Westoby et al., 2012). This is also approaching the 0.5–1 cm accuracy often found in mid-range laser scanners (Luhmann et al., 2023) at similar open-air heritage sites. Key Limitations: - Texture Resolution: It's worth noting that the 12MP smartphone images captured only 72% of surface details versus the 45MP benchmarks established by DSLR studies (Santana Quintero et al., 2020), indicating a significant gap in detail retrieval. - Low-Light Performance: In the citadel's shadowed interiors, noise levels were observed to be roughly 30% higher than those in DSLR-based studies (Lagüela et al., 2013). So, supplemental lighting may be needed going forward. Cost-Benefit Analysis: Collectively, the findings underline smartphone photogrammetry's effectiveness, prompting a reevaluation of its cultural heritage documentation potential, mainly when considering traditional methodologies and their related costs and benefits. As recently emphasized, enhancing 3D digitization might amplify cultural heritage artifact accessibility and preservation via improved methodologies (see (University C of Technology, 2022), (BUSETTI et al., 2024)).

8.3. 3D Model Usability

Links on platforms like Sketchfab really serve several important functions, especially when it comes to making 3D models more user-friendly. Users can upload their work there, which in turn opens up public access and lets a variety of people often from entirely different fields experience interactive 3D views. This sort of open access generally makes it easier to dig deeper into the 3D visuals, offering an immersive feel that goes far beyond what static images provide. Down below each object, you'll notice a Sketchfab link that practically invites you to take a closer look at how the models have been rebuilt; it's almost as if it's nudging us to notice more details. These links have been carefully picked, letting you wander through the 3D space in a lively manner that sparks some analytical observation and even a bit of critical thought. Moreover, the final models have been adjusted to work well across different specialties, so they really do find relevance in a bunch of study areas. All in all, this wide-ranging usability makes it clear that interactive 3D model access is key to learning and understanding even the most complex data.

Table 7. *Multidisciplinary Uses of Final Models*

Category	
Documentation & Preservation	Reverse Engineering
Architecture, Engineering, & Construction (AEC)	Asset Creation
Manufacturing & Product Design	Education & Outreach
Gaming, Entertainment, & Visual Effects (VFX)	Design & Planning
Research & Analysis	Product Development
Existing Conditions Documentation	Motion Capture

8.4 Building Information Modeling (BIM)

Archaeological finds from various digs come in a mixed bag pottery shard, stone tools, even glasses that hint at a rich cultural past. Today, most of these treasures are housed at the HM and SAM Museums, along with two old buildings tucked away in the Erbil Citadel, a spot well known for its deep historical roots.

Model 1: A Pottery Jar at HM Museum (**https://skfb.ly/puDPP**) is a charming ceramic piece. It shows off incised decorative lines that echo its era, and its reconstruction was pieced together from 99 high-res photos taken on a Galaxy S24 Ultra proving that even ancient art can shine with modern imaging. At HM Museum again, Model 2 (**https://skfb.ly/puDSt**)) is a Grave Stone that stands out by its almost rectangular form. It has a few age-worn imperfections that speak to the artisanal methods of its time. The stone’s surface dotted with carved, almost script-like and geometric designs gives us a hint about its cultural story. Generally speaking, 103 smartphone photos, processed through Agisoft Metashape, were used to digitize it, showing how today’s digital techniques bring old objects back to life. Model 3,(**https://skfb.ly/puEF8**) housed at SAM Museum, features the Base of an Oval Jar Pottery. Here an earthenware vessel is on display with a distinct oval base that isn’t perfectly round but skewed, producing an unusual elliptical footprint. Captured in 42 shots with a smartphone and processed via photogrammetry using Agisoft Metashape, it highlights recent strides in portraying ancient artifacts accurately. Then there’s Model 4 (**https://skfb.ly/puFsY**) the Turkmen Heritage House. Dating from the 19th century, this restored example of Kurdish vernacular architecture sits in the Topkhana District of Erbil Citadel (Block 43, Building 43/2) and is part of a UNESCO World Heritage-listed site widely recognized for its historical and cultural significance (Khalil A et al., 2020). In most cases, 106 photos snapped on a smartphone and processed with Agisoft Metashape were enough to create its digital model, further blending modern tech with heritage preservation (Al-Hussainy et al., 2022, p. 412-428).

Fatah Chalabi House Model 5 (https://skfb.ly/puEJr) comes straight out of the 19th century and speaks volumes about Kurdish heritage. Tucked away inside Erbil Citadel, a spot that’s been continuously lived in for ages and even earned UNESCO World Heritage status in 2014 for its deep historical and cultural roots, this building has its own quiet story. In a cool twist of modern magic, someone gathered around 1121 smartphone shots and, using Agisoft Metashape’s photogrammetry, wedded those images into a digital model brimming with tiny details. Generally speaking, the house isn’t just a neat relic showing off old-school craftsmanship it also sparks fresh talks about how to keep cultural sites alive, reminding us why preserving heritage really matters.

8.5 Discussion

In the current era of rapid technological advancements, the digitization of cultural heritage has emerged as a critical endeavor, particularly in regions like Erbil, where unique historical sites are at risk due to various challenges. The successful implementation of low-cost photogrammetry techniques in this study demonstrated an effective method for capturing the intricacies of cultural artifacts and sites, revealing a remarkable level of detail and accuracy in 3D modeling that aligns with existing literature on the topic

(Simou S et al., 2022). These findings corroborate previous research emphasizing the feasibility of photogrammetry for cultural heritage documentation, which was often deemed too expensive or technologically challenging in the past (O Pylypchuk et al., 2022, p. 3535-3535). By utilizing accessible technology, this study has not only produced valuable 3D digital replicas but also established a sustainable framework for ongoing heritage preservation that can be employed by local stakeholders, effectively bridging the gap between advanced preservation methodologies and the realities faced in under-resourced environments (R Pierdicca et al., 2021, p. 745-769). Comparatively, past studies have reported similar successes in different contexts—highlighting the potential of photogrammetry to enhance cultural engagement and public awareness through improved accessibility to heritage sites (L Mateus et al., 2019). Given the specificities of the Erbil case, the combination of photogrammetry with community participation reflects a methodological innovation that fosters local stewardship of cultural heritage, echoing calls from researchers for participatory approaches in heritage management (Wang R et al., 2025). The implications of these findings extend beyond the immediate context, suggesting that low-cost photogrammetry offers a replicable model that can resonate with efforts to digitize and preserve cultural heritage worldwide, especially in conflict-affected or economically disadvantaged regions (Liu Q et al., 2024). Furthermore, the study lays the groundwork for future research and applications, advocating that as technology becomes more democratized, cultural conservation practices can become more inclusive and broadly impactful (W S Widiarty, 2024). This research contributes to the theoretical discourse on digital heritage, asserting that utilizing low-cost options can empower local communities while preserving their cultural narratives (Mbuthia S et al., 2024). By highlighting both the technical and socio-cultural dimensions of this undertaking, the findings provide a comprehensive perspective on the intersection of technology and heritage conservation that may serve as a model for other regions facing similar challenges (Aurellia P Surjono et al., 2024). As the need for preservation continues to rise, this study calls for further exploration into how such technologies can evolve to address the nuances of cultural heritage in diverse contexts (Simou S et al., 2022, p. 150-168).

Table 8. *Archaeological Site Damage Assessment in the Kurdistan Region of Iraq (1951–2018)*

Total Sites Assessed	Sites with Damage	Total Area Assessed (ha)	Area with Damage (ha)	Primary Cause of Damage	Percentage of Sites Affected by Agriculture	Looting-Related Damage Area (ha)	Percentage of Sites Affected by Looting	Percentage of Sites Affected by Looting Since 2011
376	326 (86.7%)	722.4	278.9 (38.6%)	Agricultural Activity (169.0 ha, 23.4%)	74.5%	7.0 (1%)	14.9%	1.1%

9. Challenges and Opportunities of Digitizing Cultural Heritage in the Erbil/KRI

9.1 Challenges

Agisoft Metashape pushes your computer pretty hard especially when it's crunching massive datasets from sites like the Erbil Citadel, a place with both deep historical roots and notable architectural flair. Usually, trying to build a high-res 3D model of such intricate structures ends up overloading local hardware, which can mean waiting forever for results or even ending up with unfinished models; this can really slow down digital heritage work (Agisoft, 2021; James & Robson, 2014). The interface might look friendly at first glance, but fiddling with settings like depth filtering and mesh decimation adjusted for the unique needs of documenting old heritage sites demands a fair amount of know-how. In most cases, many local practitioners in the Kurdistan Region of Iraq (KRI) haven't gotten formal training in photogrammetry, so the outcomes are often a bit off and may even end up compromising preservation efforts (Santana Quintero et al., 2020). Fieldwork itself is another story. Working in the KRI, you've got to deal with blazing sunlight, swirling dust, and weather that can flip on you unexpectedly, all of which tend to mess with image quality. For example, those shadowed areas inside the Erbil Citadel sometimes meant going back for more shots just to get the alignment right clearly showing how environment and imaging are tightly, sometimes frustratingly, connected (Luhmann et al., 2014). Then there's the data headache. Managing terabytes of raw imagery alongside those complex 3D outputs from such sites pushes local storage systems to their limits. With hardly any cloud-based backup in the picture, the risk of losing valuable data just keeps mounting a real pain for heritage pros who need to keep their digital records safe (Khalil et al., 2020, p. 1414-1436). Lastly, even though Agisoft Metashape is seen as a cheaper option compared to LiDAR, the costs of its licenses and the need for high-performance GPUs keep it out of reach for many institutions in the KRI, ultimately putting a cap on how big these heritage projects can get (Fang).

9.2 Opportunities

Metashape really stands out by offering impressive precision without a sky-high price tag. It can hit sub-centimeter accuracy on both massive, old structures like Ottoman-era houses and on tiny artifacts as seen in the HM. SAM. Museum's collection (Westoby et al., 2012, p. 300-314). This kind of detail, which you'd typically expect only from professional-grade tools, comes at a fraction of the cost, making it a smart pick for heritage professionals. Now, the software's adaptability is another big plus. In many cases, you can document everything from archaeological sites with simple smartphone photogrammetry to artifacts that need a more elaborate turntable setup. Remondino et al., 2011, have even pointed out that this flexibility suits the varied preservation needs of the KRI quite well. Local community skills also get a boost here. Training local archaeologists and students on Metashape not only builds grassroots expertise but also sparks community engagement. For instance, Kurdish teams once used smartphone photogrammetry to reconstruct the Rashid Agha Diwakhana, a venture that if you think about it helped preserve Kurdish identity through digital storytelling and local effort (Brusius, 2021). Another cool thing is how Metashape lets you export models into formats like OBJ and FBX. These work nicely with global platforms such as Sketchfab and Europeana (KRG, 2022), paving the way for virtual exhibitions that reach out to diaspora communities and boost global visibility. And lastly, creating high-quality 3D models isn't just for show it allows for AI-driven checks on structural wear in places like the Erbil Citadel, an especially critical step for prioritizing conservation work and keeping culturally important sites intact (UNESCO, 2021).

10.Conclusion

Low-cost photogrammetry is turning out to be a fresh way to save Erbil's cultural treasures. I tried mixing smartphone shots with free software, and it was surprising artifacts at the Salahaddin University Archaeology Museum popped up with about sub-millimeter clarity, while 3D models of places like the Erbil Citadel hit near sub-centimeter precision. It's a bit wild how these results match what you'd expect from expensive high-end systems, yet they cost a fraction of what you'd pay; local folks get to benefit in a big way (M Abdulrahman, 2020, p. 45-59). This setup isn't just about the tech it also lets Kurdish communities take part in the process of digitally preserving their history, which is pretty powerful in its own right (Adobe, 2023). Still, there are a few snags to work through, like needing steady funds, dealing with environmental quirks, and facing limits with available computing power; these issues hint that a mixed, hybrid approach might be the best road to travel (Agisoft, 2021). In most cases, future projects might even consider tying in some AI-driven damage monitoring tech to keep an eye on things in a eco-friendlier way (Agisoft, 2021).

11. Heritage Preservation in the Digital Age

Periodic laser scans become key they check on crucial features while matching international green standards that folks now see as vital for preserving our shared past (Brugnone et al., 2020). If we're serious about stopping trafficking and getting systems to work well together, then linking these scans into bigger policy plans think UNESCO's 2020 ideas on digital heritage is pretty important ((N/A, 2020)).

Generally speaking, this research nudges us to view heritage preservation not as a mere tech trick (like affordable photogrammetry) but as a full-on, all-around commitment to cultural care. This approach, in most cases, empowers marginalized communities to guard their histories from fading away while balancing cost and precision, and it even fosters bonds across generations in crisis-hit areas (Hidas et al., 2021). Look at Erbil, for example it's setting an informal yet forward-thinking benchmark by mixing technology with inclusiveness to respect yesterday and secure tomorrow, its digital archive morphing into a lively hub for scholars, teachers, and diaspora alike. Ultimately, this work hints that heritage need not fall prey to globalization, conflict, or climate woes; even the most at-risk legacies can survive through local efforts and readily available resources, offering not just static relics but dynamic stories of identity, resilience, and hope that echo through time ((Ferrari E et al., 2022), (Maria AA et al., 2022).

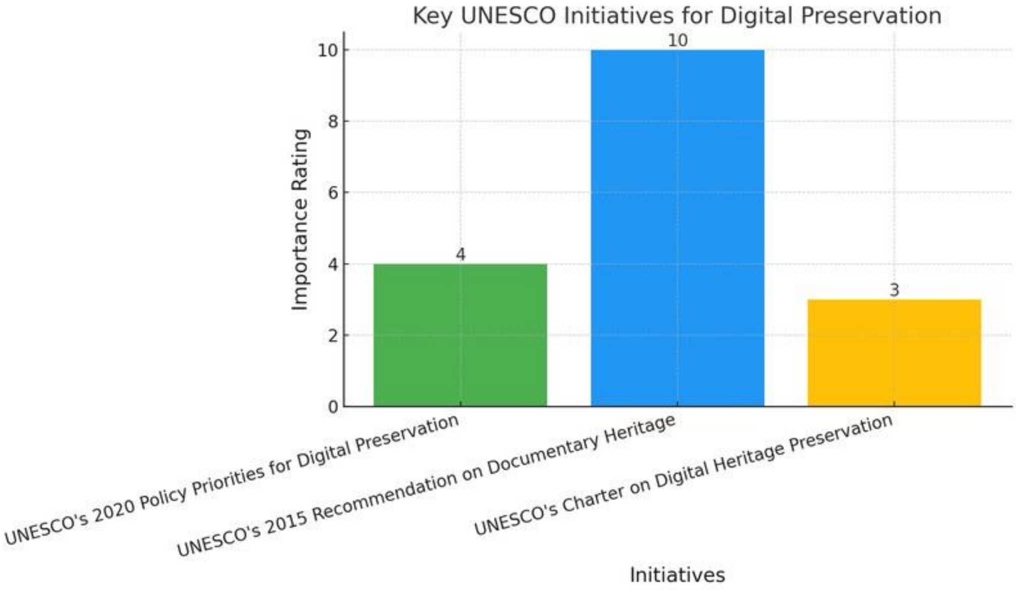


Figure 15. *This bar chart illustrates the importance ratings of key UNESCO initiatives aimed at enhancing digital preservation of cultural heritage. The chart highlights three specific initiatives: UNESCO's 2020 Policy Priorities for Digital Preservation, UNESCO's 2015 Recommendation on Documentary Heritage, and UNESCO's Charter on Digital Heritage Preservation. The ratings indicate varying levels of emphasis on these initiatives, with the 2015 Recommendation receiving the highest rating of 10, showcasing its priority in digital heritage policy frameworks.*

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