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Photogrammetry As a Technology for Preserving Architectural Heritage: An Applied Study of The Al-Maqam Mosque in Basra

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ABSTRACT

Many countries aim to preserve their cultural heritage, encompassing both tangible and intangible aspects. This is achieved through various techniques, including digital methods, to record and document heritage buildings. One of the most prominent and widely used techniques is Photogrammetry, which is used for both three-dimensional and two-dimensional levels. Numerous studies have explored this technique and discussed its application to various types of buildings, including heritage and archaeological structures. The reviewed literature reveals a lack of application of this technique in architectural studies focused on preserving the built heritage of the city of Basra, particularly buildings with a religious character, such as mosques, which are considered significant elements of Basra's cultural and architectural heritage. According to this, the research aims to build a virtual model of Al-Maqam Mosque in the city of Basra using Photogrammetry, as this mosque holds significant value in the urban landscape of the city and represents an important architectural and cultural heritage building. The research demonstrates that the photogrammetry technique plays a crucial role in documenting architectural heritage with high efficacy, transforming photographic images of buildings into precise 2D and 3D geometric models.

الكلمات المفتاحية

الفوتوغرامميتري، البصرة، العشار، الحفاظ، التراث.

الملخص

تسعى العديد من الدول الى الحفاظ على تراثها المادي وغير المادي، ولغرض تقليل الضرر او حفظ هذا التراث العمراني من الضياع استخدمت تقنيات متعددة، منها التقنيات الرقمية، لأجل تسجيل المباني التراثية، ومن ابرز هذه التقنيات وأكثرها شيوعاً وهو الفوتوغرامميتري، على مستويين الثلاثي الابعاد او ثنائي الابعاد اذ تطرقت العديد من الدراسات الى هذه التقنية وكيفية تطبيقها على المباني المختلفة، ومنها المباني التراثية والاثريّة، ومن خلال نقد الدراسات الطروحات السابقة تبين وجود فجوة معرفية متمثلة بعدم وجود دراسة معمارية تبين اهمية هذه التقنية في حفظ التراث العمراني لمدينة البصرة، وبالأخص الابنية ذوات الطابع الديني، والمتمثلة بالجوامع، لما تشكله هذه الابنية من تراث عمراني وثقافي مهم لمدينة البصرة وبذلك تمثل هدف البحث في بناء نموذج افتراضي لجامع المقام في مدينة البصرة باستخدام تقنية الفوتوغرامميتري، لما يمثله هذا الجامع من اهمية في التراث العمراني والثقافي للمدينة، لغرض حفظ هذا المبنى، وصولاً الى الاستنتاجات والتوصيات الخاصة بالبحث.

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1. Introduction

Recognising the significance of architectural heritage in various cities, methods for preserving and recording buildings have evolved. Among these methods are modern digital techniques that utilise images, commonly referred to as Photogrammetry. This research delves into this term to explore the characteristics of this type of digital technology and its importance in heritage preservation. The study examines previous architectural research that has either directly or indirectly addressed this topic. The research categorises these studies into two groups: those that focus on photogrammetry technology and those that concentrate on documenting or recording buildings in the city of Basra. This highlights the research problem, which is the lack of a specialised study that investigates the importance of Photogrammetry in preserving the historic buildings of Basra, particularly religious buildings such as the Al-Maqam Mosque in Ashar city of Basra. Given the mosque's significance in Basra's religious and cultural heritage, the aim is to construct a virtual model of the mosque using digital techniques for preservation purposes.

Furthermore, this would, in turn, facilitate the documentation of other historic buildings. The research has reached the importance of this technology in documenting heritage buildings by capturing images and transforming them into three-dimensional forms, which facilitates their preservation and maintenance, as well as measuring the temporal changes that have occurred in historical or heritage architectural structures. Using an applied scientific research methodology, the study focused on buildings of historical, cultural, or distinctive design significance. The research also identified the positives and negatives of this technology, indicating that its use is crucial in preserving the urban heritage of the city, particularly the tangible heritage. The study recommended the necessity of employing this technology, leading to various conclusions and recommendations.

2. Literature Review

Numerous studies and theses have highlighted the significance of digital technologies in recording and documenting buildings. While these techniques are varied, they share a common goal: preserving architectural heritage and revitalising tangible cultural heritage, which underscores its significance. This research has categorised previous studies into two groups: one focusing on modern digital techniques for building documentation and the other specialising in documenting historic buildings in Basra.

Among the studies on digital techniques in architectural documentation and recording, Fayez (2011, p. 464) explored 3D documentation using Photogrammetry to revitalize the historical district of Sur. The study concluded that this technique is crucial for preserving architectural heritage, especially in 3D modelling. The study by Al-Minshawi et al. (2016, p. 165) focused on the most important digital techniques for documenting heritage and archaeological buildings, as well as their various applications in archaeology. Ajout et al. (2021, p.346) focused on photogrammetric scanning for documenting archaeological sites, including the Baz Lyka at the Ayuminium site. The researchers noted that this technique is a modern, time- and cost-effective method for 3D architectural documentation and study (Mohamed et al., 2021, p. 449). The researchers demonstrate the possibility of modelling submerged archaeological sites using Photogrammetry for the Lighthouse of Alexandria. This research emphasised the need for digital software in documenting archaeological sites and architectural heritage. Another study examines the increasing role of digital technologies, particularly Photogrammetry, in the conservation, documentation, and diagnosis of architectural heritage. Recent advancements in close-range and aerial Photogrammetry have made these tools more accessible, cost-effective, and automated, enabling broader adoption by conservation specialists rather than remote sensing experts (De Fino et al. 2023. P.4). study by (Mohammad 2022, p. 440) addressed modern techniques in documenting buildings, specifically ground-based laser scanning technology, and its potential use in heritage preservation. The researcher discussed the importance of this technique and its various applications.

Yiğit et al. (2024) investigated the application of Photogrammetry to rapidly identify cracks and structural damage in heritage buildings—a significant threat to preservation efforts. This method enhances diagnostic accuracy in structural risk assessments. (Yiğit et al. 2024. p1). Iqbal et al. (2024). The study examined the cultural resistance of heritage cities to various factors and explored the potential of using digital documentation to document urban heritage in the city of Mosul (Iqbal et al., 2024, p. 18). Kahachi, et al. (2025) and Al-Majidi et al (2015). The two studies discussed the importance of preservation,

sustainability, and digital documentation of buildings and their significance in preserving architectural heritage (Kahachi et al, 2025, p95 95; Al-Majidi et al, 2015, p.307).

The second group of studies focused on the architectural documentation of Basra. (Markarian, 2012, p. 6) addressed the concept of documentation in general and architectural documentation in particular for Basra during the late Ottoman period until 1958. The study examined numerous buildings from this period using both manual and digital documentation methods. The researcher concluded that architectural documentation is essential for preserving the city's historic buildings. Prof. Dr. Khalil et al. (2014, p. 377) discussed the documentation of architecture in the city of Basra, using a combination of traditional and electronic methods. The researchers emphasised the importance of the documentation process in preserving urban heritage models. Markarian (2018, p. 142) examined the role of photographic documentation in preserving the city's architectural heritage. The researcher relied on manual recording of images of buildings along the Shatt al-Arab River from 1930 to 1950. Subsequently, the researcher digitally recreated the riverfront, resulting in a virtual reconstruction of the area.

Markarian et al. (2021, p. 408) documented Ottoman-era architecture in the Basra and Al-Ashar districts, highlighting the most significant buildings constructed during that period and their characteristics. This study emphasised the importance of these buildings in the city's architectural history and documented them through plans and photographs. Al-Tamimi (2008, p. 1) explored several mosques in Basra and examined their social and cultural impact on the city's community. These mosques were documented within a geographic area encompassing the city centre, providing historical information such as the building's name, location, construction style, and endowment; however, they did not examine the architectural details or development in detail. Al-Gharib (2007, p. 117) examined the mosques in the centre of Basra during the Ottoman period. The study categorised the mosques into four groups: those built by governors and administrators, those built by religious circles, those built by professionals or craftsmen, and those built by neighbourhoods. The study provided historical descriptions of each category, including construction dates and significant historical changes, but did not delve into architectural characteristics or features. A critical analysis of the previous studies reveals a knowledge gap: the absence of specialised studies using Photogrammetry to document the city's architectural heritage, particularly religious buildings such as the Al-Maqam Mosque. This research will address this gap by exploring this technique and demonstrating its potential for recording historic buildings for preservation purposes. This research aims to demonstrate the significance of digital programs in documenting and recording the architectural heritage of historic buildings, especially religious ones, in Basra. Specifically, it seeks to construct a virtual model of the Al-Maqam Mosque in Basra using photographs and photogrammetry software.

3. Methodology

This research employs a multi-stage methodological approach to evaluate the Technique of Photogrammetry for urban heritage conservation. The research framework, as illustrated in Figure (1), comprises two principal phases of data collection. The first phase involves historical documentation, focusing on Basra's Al-Ashar district as a case study due to its historically significant religious architecture, particularly the Al-Maqam Mosque. This phase establishes the spatial and temporal parameters of the research through archival analysis and historical mapping. The technical documentation phase applies a standardised data collection framework comprising three integrated procedures. The process begins with photogrammetric surveys to comprehensively document the Maqam Mosque, followed by the creation of an architectural plan using AutoCAD. The final stage involves creating a 3D model using the 3D ZAPHER PROGRAM. These methodological components facilitate the production of precise three-dimensional simulation models, which serve as critical tools for heritage conservation initiatives.

The Historical Foundations and Urban Development of Basra: Many factors contributed to the formation of Basra, with the military playing a significant role in its development. Basra was initially a primitive military camp for Arab Islamic forces, consisting of simple tents and domes distributed across seven small villages. Under the leadership of Utbah ibn Ghazwan, the city began to expand eastward, opposite the soldiers' positions, and a specific mosque formed the core of Basra (Al-Ali, 1948, pp. 72-83). After being destroyed by multiple wars and invasions, Basra was relocated to its current site, now known as Old Basra, and urban growth subsequently extended toward the Al-Ashar area (Al-Anzi, 1997, p. 19).

The Maqam suburb, situated within this area, initially served as the nucleus of the Al-Ashar neighbourhood, despite being barren land covered by swamps (Al-Abbasi, 1988, p. 242).

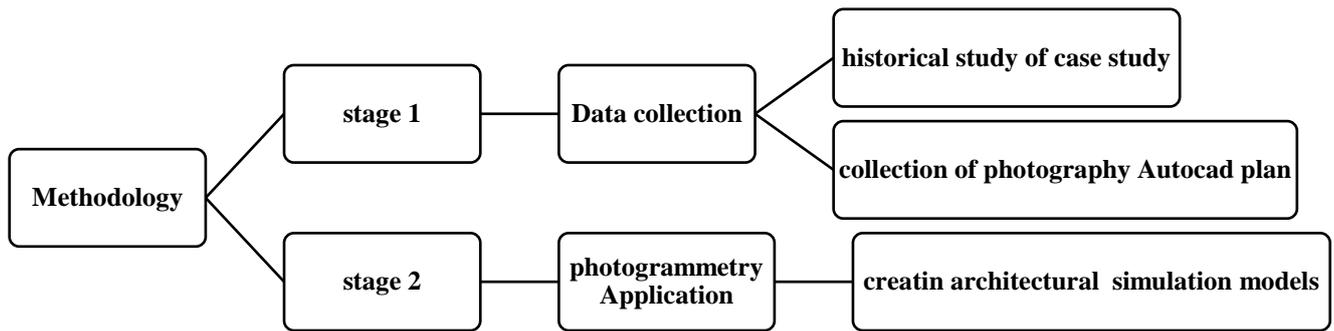


Figure 1. The research methodology used. Source: (Design by authors).

The area's architectural landmarks were limited to a mosque and a maqam. No significant development began until 1870 under Midhat Pasha, who moved the administrative palace to the suburb. This initiative included the construction of government buildings, customs facilities, a port, and a quarantine station. To encourage settlement, Midhat Pasha leased government-owned land; however, subsequent governors, including Nasir Pasha, imposed restrictions prohibiting settlement outside the official city limits—a policy that excluded the shrine and temporarily stifled its growth (Barakat, 1984, pp. 101-118). Al-'Ashar subsequently developed into Basra's primary commercial port by 1895, marking a period of steady economic growth. The area continued to develop into the secondary core of modern Basra, marking a crucial stage in its urban development. Figure (2) shows the historic city of Basra and the entrance to the Shatt al-Arab.



Figure 2. View of Basra in 1695 by Dutch cartographer Saak de Graaf. Source: (Abdullah, 2001: p. 56).

Al-Maqam Mosque: One of the well-known mosques in the city of Basra, located in the Al-Ashar district. The reason the mosque was named "Al-Maqam" (The Station/Rank) is in reference to the "Dar Al-Maqam Al-Ali" (The House of High Rank) that existed before its establishment. "Dar Al-Maqam Al-Ali" was a customs department belonging to the state. It is one of the largest mosques in Basra, distinguished by its beautiful Arabic mosaics that cover the dome and minaret (Aljabri, 1959, p. 60). It was built during the Ottoman period in 1754, funded by Sultan Abdul Hamid, and constructed by Haj Muhammad Al-Shashteri. The mosque is distinguished by its beautiful architecture, intricate interior decorations and carvings, a distinctive entrance, and a dome covered with glazed tiles (Al-Samarraie, 2010, pp. 46-47). The prayer hall can accommodate between 400 and 500 worshippers. The mosque is named after the Ottoman High Court (Customs Department) building that belonged to the Ottoman Empire (Abdul Wahhab, 2021, p. 12). Some sources suggest that the name may originate from a shrine known as the "Maqam Ali" and that the mosque was built adjacent to this shrine (Al-Sultan, 2001, pp. 16-17). See Figure (3).



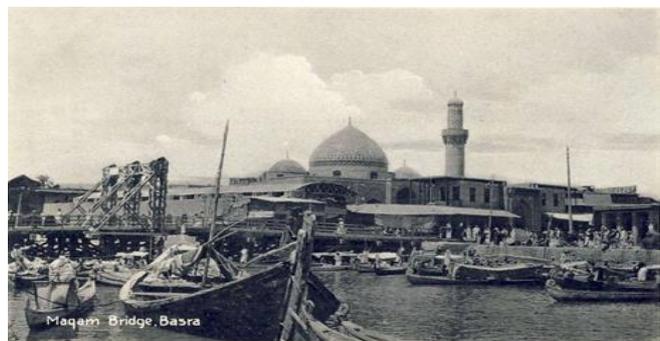
Figure 3. Location of Al-Maqam Mosque and surrounding buildings. Source: (General Directorate of Urban Planning, 1991).

Despite differing opinions regarding the origin of the suburb's name or the shrine, the importance of both is emphasised. The total area of the mosque is approximately 600 square meters (Basra Heritage Centre, 2016), while the prayer hall is approximately 450 square meters. It has three doors and upper windows that serve as air vents for the prayer hall. In the centre is a mihrab, and to its right is a minbar, both covered with brick and glazed Karbala tiles. The prayer hall features three domes, the largest of which is the central one, constructed of fired brick and measuring 8 square meters. It has eight windows. The two smaller domes, each approximately 4 square meters in size, underwent renovations in 1997 and 2013. It is worth noting that old photos of the mosque show four domes, as the fourth dome was located in the mihrab. The mosque also has a courtyard with a minaret that is approximately 25 meters tall and underwent renovations in 1997. The mosque has a dedicated room for the imam, preacher, and muezzin (Al-Maqam Mosque, 2020).

The mosque has undergone numerous restoration and renovation projects in 1922, 1979, 1997, 2008, and most recently in 2013. During these projects, the floors, prayer hall, and entrances were renovated, and some of the fired brick floors were replaced with shotcrete and then tiled, as shown in Figure (4).



a. Historical photograph of Al-Maqam Mosque. Source: (Past century Postcards, 2025)



b. Al-Maqam Mosque with the adjacent Al-Maqam. Source: (Past century Postcards, 2025)



c. Contemporary photograph of Al-Maqam. Source: (Aljabri, 1959: p.57).



d. Al-Maqam Mosque and the covered market (souq). Source: (Aljabri, 1959: p.57).



e. Dome structures of Al-Maqam Mosque. Source: (Ahmed, 2024).



f. Surrounding activities and urban context near Al-Maqam Mosque. Source: (Ahmed, 2024).

Figure 4. Al-Maqam Mosque in different historical stages.

As shown in the following images, the mosque is located on the former Queen's Road (currently Dakir Street), which is an extension of the former King Faisal Road (currently Al Watan Street), (Basrah Survey Party. 1917. No. 86. p.5). The mosque is also adjacent to a covered market, as a development plan was proposed to remove the market and convert it into gardens belonging to the mosque. This is evident in the development plans drawn up by Max Lock, which also included the neighbouring area (currently Lion of Babylon Square) (Max Lock, 1956, p.19), as shown in Figure (5).

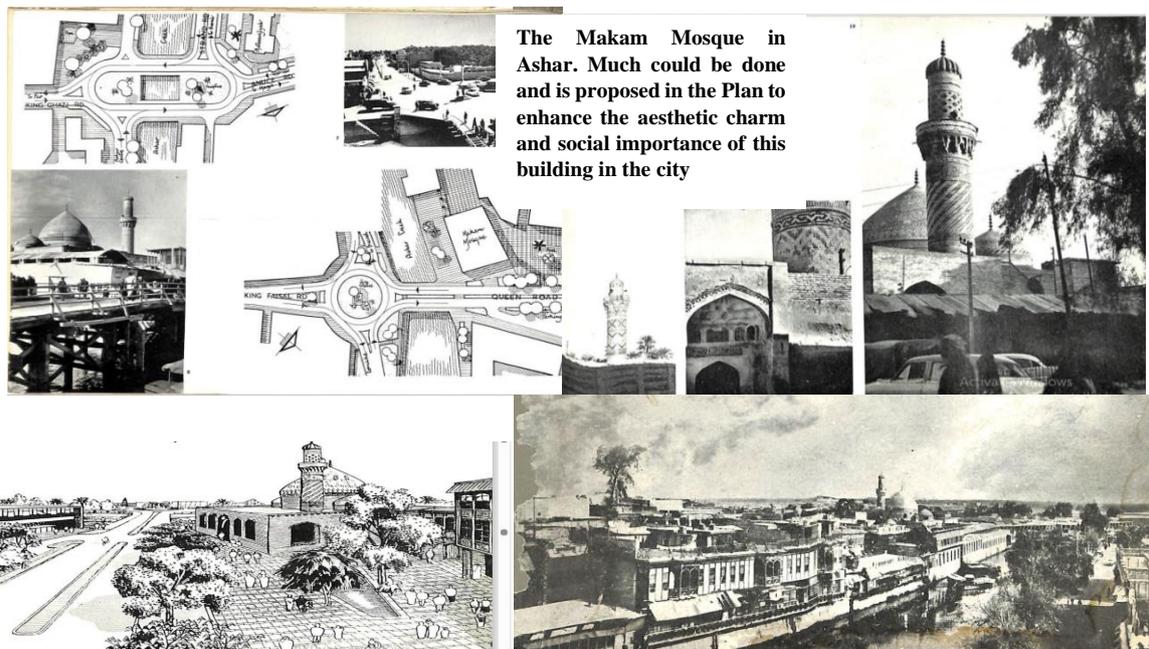


Figure 5. A proposal for the development of Al-Maqam Mosque Street and the surrounding area in 1955. Source: (Max Lock, 1956, p.19).

4. Photogrammetry and Its Applications

The next part of the study will explain the concept of Photogrammetry, its history, definition, and uses, as well as the software used to convert photographs into 3D models. Sources indicate that the first application of photographs to create maps was by a French military engineer named Aimé Laussedat in 1848, who created an aerial map of Paris in 1867. This technology has undergone significant developments, including the emergence of topographic maps during World War II, as well as the introduction of digital cameras and various advanced devices and technologies for surveying and different studies (Photogrammetry, 2019).

4.1. Photogrammetry

Photogrammetry is both an art and a science focused on obtaining 3D information from photographs. This technique involves capturing multiple overlapping images of an object, structure, or even an entire space. These photographs are then transformed into 2D or 3D digital models. Professionals across various fields, including surveyors, architects, engineers, and contractors, frequently utilise photogrammetry software. They leverage it to generate a range of outputs such as topographic maps, detailed meshes, point clouds, or precise drawings that accurately represent real-world environments (Autodesk, 2024).

Photogrammetry, also known as photogrammetric surveying, is derived from the French language and consists of three Greek roots: photo (image), gamma (light), and metron (measurement or dimension) (Ajout et al., 2021, p. 347). It is defined as the science and technology of documenting buildings or different environments by recording, measuring, and interpreting photographic images to obtain accurate three-dimensional information and terrain characteristics from two-dimensional images. This technique can be applied to measure coordinates, estimate distances, elevations, areas, and volumes, and prepare topographic maps. Photogrammetry is an advancement of traditional photography, which previously relied on visual spatial techniques. It has evolved to depend on digital images, mathematical algorithm analysis, and computer software. Photogrammetry encompasses several types, the most significant of which are aerial photography (where the camera is positioned in the air) and terrestrial photography (utilising a handheld camera) (James et al., 2010).

4.1.1. 3D Zephyr Software: 3D Zephyr

3D Zephyr is a software tool for applying photogrammetry techniques. It operates by inputting a large set of images and processing them to create 3D models of buildings or groups of buildings. It has several applications, including:

- Recording and documenting heritage buildings or archaeological and historical artefacts.
- Creating architectural simulation models.
- Use in gaming and animation.
- Virtual reality (VR) and augmented reality (AR): Producing immersive experiences by modelling real-world locations (3Dflow, n.d.).

4.1.2. How to Apply the Photogrammetry Technique

To apply Photogrammetry effectively, the following steps should be followed:

- Image overlap: Images should overlap approximately 60% in both the vertical and horizontal directions. Camera-to-object distance: The distance between the camera lens and the building should be constant at all shooting angles to minimise depth distortion. Camera resolution: A high-resolution camera (preferably 24 megapixels or higher) is recommended to improve detail capture and enhance model accuracy, as shown in Figures (6), (7), and (8).

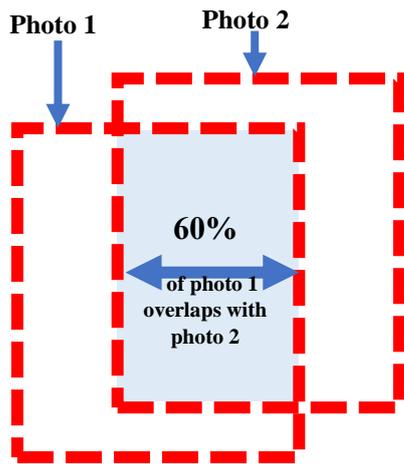


Figure 6. Photo overlaps. Source: (Authors).

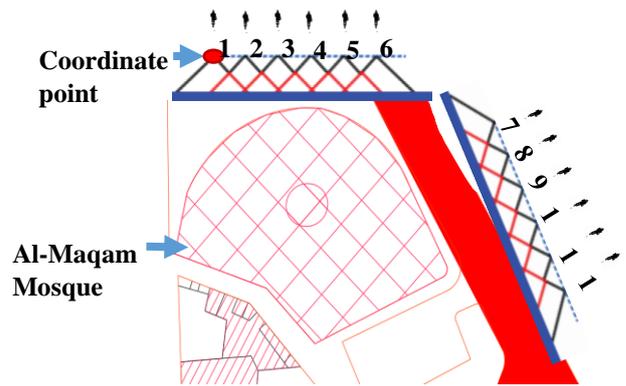


Figure 7. Camera-to-object distance. Source: (Authors).

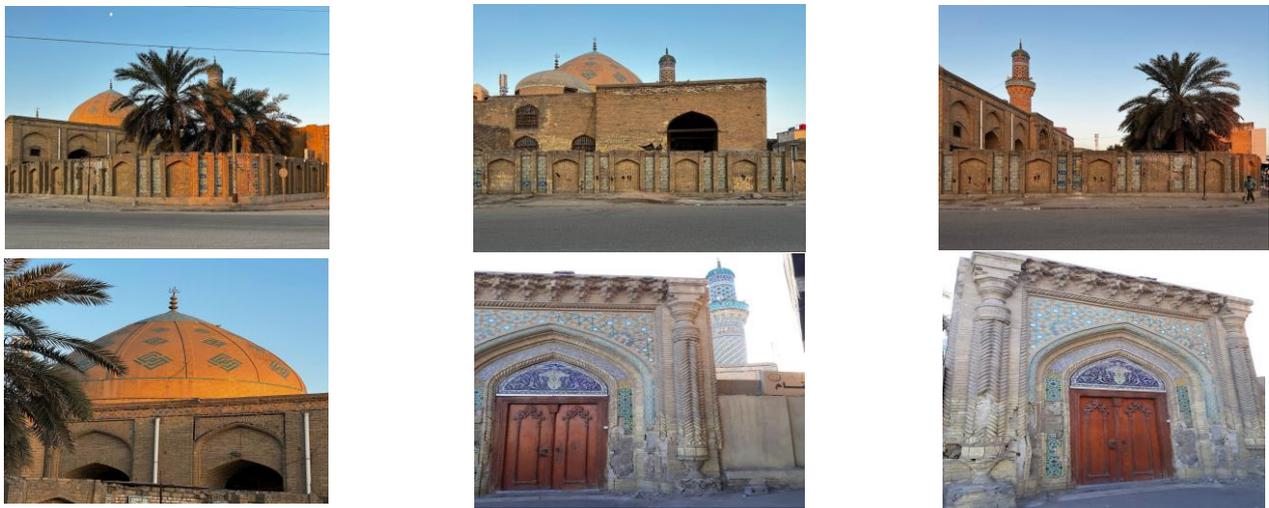


Figure 8. A selection of Al-Maqam Mosque photos used for the program. Source: (Taken by authors).

- Exporting Images to 3D Zephyr: The images are exported to the 3D Zephyr software to identify key features by recognising common points between images (overlapping features between images), such as shared corners and edges. The software then calculates the camera's position and orientation and determines the 3D coordinates of the points.
- Creating a Point Cloud: A 3D representation of each feature point's position in the 3D space is created, forming a point cloud.
- Creating a Mesh: A 3D mesh is generated by connecting the points in the dense point cloud.
- Applying Textures: The original images are used to apply textures to the 3D Model. This adds colour and realistic details, closely matching the details in the original images, as shown in Figures (9) and (10).

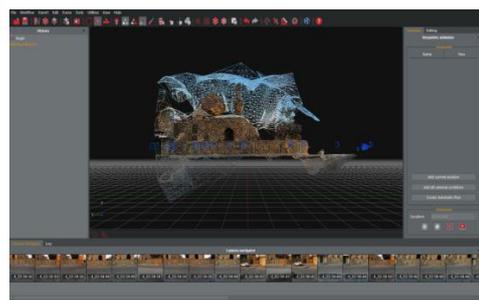
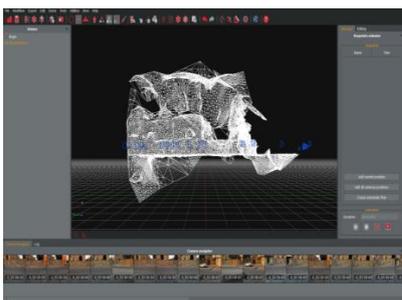


Figure 9. Steps outlining the process of creating the 3D Model within the software dedicated to the Al-Maqam Mosque in Basra city. Source: (Authors with Eng. Ahmed Maher Mohammed).



Figure 10. Results of the 3D Model of Al-Maqam Mosque using the software. Source: (Authors).

This process allows for the creation of highly accurate and detailed 3D models from 2D images. Model Export: The completed 3D Model can be exported in various formats for reuse in different software and applications, such as CAD programs and other multi-purpose software, as shown in Figures (11), (12), (13), and (14).



Figure 11. Final results for the 3D Model within the software dedicated to the Al-Maqam Mosque in Basra city. Source: (Authors with Eng. Ahmed Maher Mohammed).

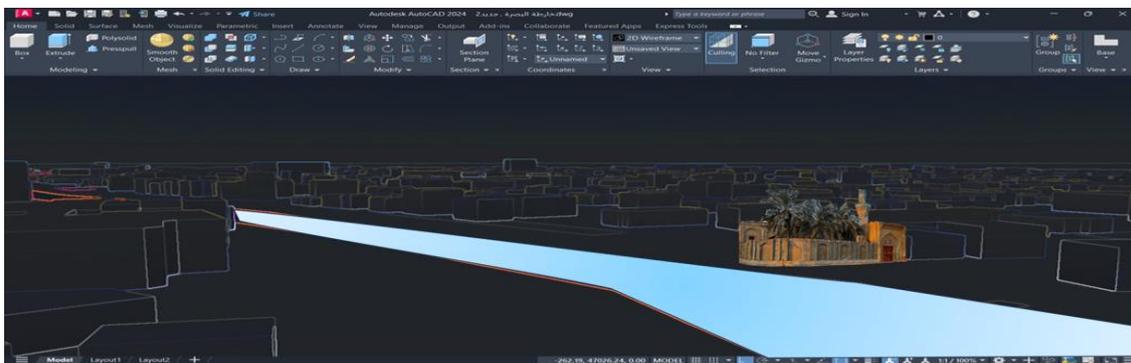


Figure 12. Final results for the 3D Model within AutoCAD software. Source: (Authors with Eng. Ahmed Maher Mohammed).

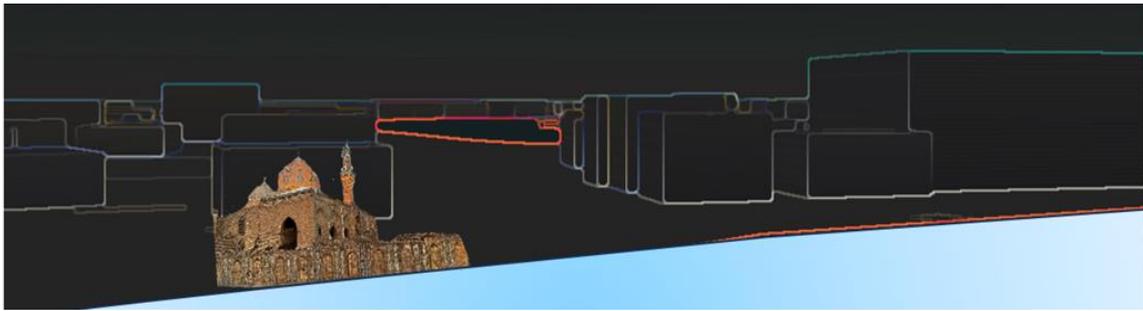


Figure13. Final results for the 3D Model in AutoCAD ,the CAD software. Source: (Authors with Eng. Ahmed Maher Mohammed).



Figure 14. The main gate of the Al-Maqam Mosque entrance was created in the photogrammetric software. Source: (Authors with Eng. Ahmed Maher Mohammed).

5. Results of the practical study

The findings demonstrate that Photogrammetry is a user-friendly and cost-effective technique that can be implemented using a smartphone camera and simple software, such as 3D Zephyr, to save time and effort when creating three-dimensional models with complete architectural details from two-dimensional photos. Additionally, the technique yields better results for façades than full 3D models, which can be utilised for documenting urban façades, streets, and the heritage alleys surrounding Al-Maqam Mosque. The results also highlighted the precise documentation of the architectural details that distinguish Al-Maqam Mosque, such as doors, entrances, Islamic decorations, carvings, and finishing materials. It provides the opportunity to create a specialised model for these details, enabling their development and the restoration of damaged sections.

However, the study encountered several challenges, including selecting a suitable heritage building as the study sample—namely, the Al-Maqam Mosque in the city of Al-Ashar. This building is difficult to capture from all four sides due to its proximity to neighbouring buildings, as well as the height of the minaret and dome, which necessitated adjustments in the focal length of some images. Environmental conditions and weather changes are perceived as obstacles to using this technique, as it relies on the amount of solar radiation and the resulting shadows, which fluctuate throughout the day and across different seasons. Some natural obstacles also existed, such as trees covering part of the main façade, the height of the wall surrounding the building, and other obstacles, including wires and lampposts. These combined factors influenced the quality of the final outputs obtained for the Al-Maqam Mosque model, which

consisted of creating two models: one for the mosque itself and another for the main entrance. The practical study demonstrated the feasibility of creating 3D models of various buildings, given their great architectural significance and the importance of preserving and documenting them.

6. Conclusions

This study highlights the role of computer software in documenting urban and architectural heritage. It facilitates the precise engineering documentation of buildings, thereby enhancing their preservation and archival potential. The study confirms that Photogrammetry effectively converts building photographs into precise two-dimensional (2D) and three-dimensional (3D) geometric representations. Consequently, the application of this technique within architectural studies significantly contributes to the preservation of heritage buildings that are vulnerable to neglect and deterioration due to factors such as inadequate maintenance, misuse, conflict, or structural aging. It enables the high-quality documentation of a larger corpus of heritage buildings within a condensed timeframe. Ultimately, the research underscores the substantial contribution of these technologies to the advancement of heritage building documentation and recording practices.

Additionally, the integration of Photogrammetry supports urban renewal and preservation processes in heritage-rich areas by optimising time and resource efficiency. Ultimately, this technology enables us to create precise digital models, thereby eliminating potential human errors that can occur when using traditional documentation methods, such as manual measurements and sketches. This technology also facilitates the creation of a database of heritage buildings, which supports their development and renovation, and helps detect structural deterioration, thereby accelerating maintenance processes. Moreover, this technology significantly reduces the time and effort required for the documentation process. Ultimately, this technology enables us to develop accurate digital models, thereby reducing the potential for human errors that can occur with traditional documentation methods, such as manual measurements and sketches. This technology also enables the creation of a database of heritage buildings, supporting their development and renovation, and assisting in identifying structural deterioration, thereby speeding up maintenance processes. Moreover, this technology considerably reduces the time and effort needed for documentation.

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