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Drone Technology: A digital twin concept for improving operational efficiency in Preservation Projects

Done by

Islam Elghonaimy*, **Kawthar Ghasrah****, **Dalia H. Eldardiry*****

*,** University Of Bahrain, College of Engineering, Department of Architecture and Interior Design.

***Imam Abdulrahman Bin Faisal University, College of Design, Saudi Arabia

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Acknowledgment

This pilot project was conducted successfully using the cooperation between the private (“LIF” Consultant Architecture Office) and academic (Department of Architecture and Interior Design, College of Engineering, University of Bahrain) sectors to propose a maintenance method that the governmental sector could use to operate open spaces in an innovative, sustainable way.

Introduction

Cultural Heritage MAINTENANCE, PRESERVATION, AND CONSERVATION

Cultural Heritage & ancient sites, such as settlements, forts, and mosques, face **threats from environmental degradation, urbanization, and neglect.** Traditional documentation methods for MAINTENANCE, PRESERVATION, AND CONSERVATION are often costly, limited in scope, ineffective in certain circumstances, and prone to risk.



Introduction

Cultural Heritage MAINTENANCE, PRESERVATION, AND CONSERVATION

Moreover, Traditional techniques could not be effective in some places as they can be time-consuming, highly skilled, labor-intensive, and inadequate for capturing the comprehensive data required for practical MAINTENANCE efforts.



Introduction

Cultural Heritage MAINTENANCE, PRESERVATION, AND CONSERVATION

In response to these limitations, the concept of a digital twin for improving operational efficiency in **MAINTENANCE, PRESERVATION, AND CONSERVATION** projects has emerged as a promising alternative, with drone technology offering new possibilities for more efficient and accurate heritage documentation



Introduction

Drones as a Solution

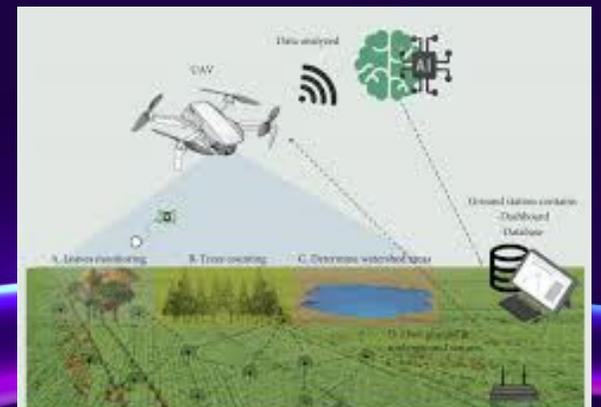
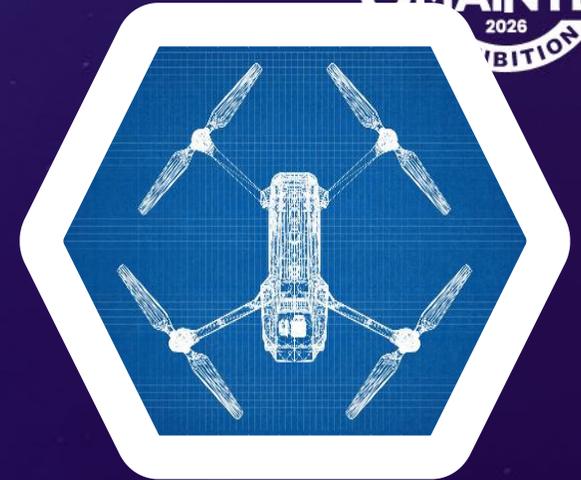
Drone technology offers a non-invasive and cost-effective means of documenting heritage sites for

MAINTENANCE, PRESERVATION, AND CONSERVATION

PROJECTS, creating detailed 3D models, and providing access to previously inaccessible **areas**.

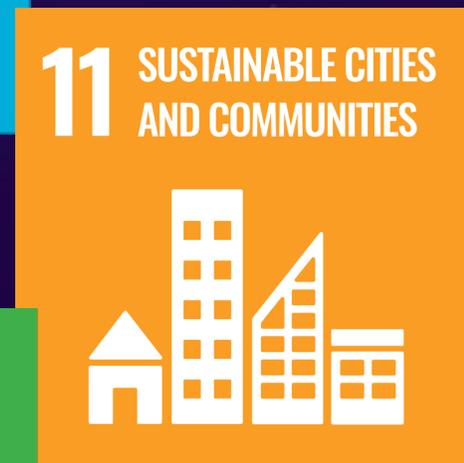
Despite these benefits, regulatory and technical challenges limit their use.

In addition, it should meet the **SDGs & Cultural Heritage**



Introduction

Meeting SDGs & Cultural Heritage



Introduction

The pilot conceptual project Emphasis

This pilot project explores how DRONES CAN ENHANCE documentation and follow-up of heritage sites in MAINTENANCE, PRESERVATION, AND CONSERVATION in CULTURAL HERITAGE PROJECTS.



THE IMPORTANCE OF HERITAGE CULTURAL PRESERVATION

The pilot project Focus

Heritage Cultural preservation involves protecting heritage, both **TANGIBLE** (buildings, monuments) and **INTANGIBLE** (traditions, languages), for future generations (Okoli et al., 2023).

It helps **MAINTAIN CULTURAL IDENTITY** and values, connecting people to their past while strengthening national identity amid globalization and urbanization.



THE IMPORTANCE OF HERITAGE CULTURAL PRESERVATION

The pilot project Focus

In ADAPTIVE REUSE projects, the goal is to maintain the INTEGRITY of MAINTAINING, PRESERVING, AND CONSERVING heritage buildings while adapting them to serve CONTEMPORARY functions, thereby preserving their cultural significance.



THE IMPORTANCE OF HERITAGE CULTURAL PRESERVATION

Moreover, Digitization has become a revolutionary method in reaction to these challenges. Using drone technology can improve the **ACCURACY, EFFICIENCY, AND AVAILABILITY** of documenting heritage sites, helping to reach that objective. Drones provide detailed 3D models, high-resolution images, and comprehensive site data, offering significant benefits compared to traditional methods.



THE STUDY PROJECT QUESTIONS

This project's idea will assist in answering the study questions: "How can drone technology enhance the **MAINTENANCE, PRESERVATION, AND CONSERVATION** of built cultural heritage? Furthermore, what are the comparative strengths and challenges of drone-based versus traditional methods.



METHODS OF USING DRONES IN SUCH PROJECTS

Restoration:

- Focuses on returning a cultural asset to its original state.
- Removes alterations or reconstructs missing elements.
- Aims to maintain the aesthetic and historical integrity of the site.

Conservation:

- Preserves the material authenticity of heritage sites without major changes.
- Prevents further decay while maintaining the original structure.
- Uses diagnostic techniques to assess and protect historical materials.

Digitization:

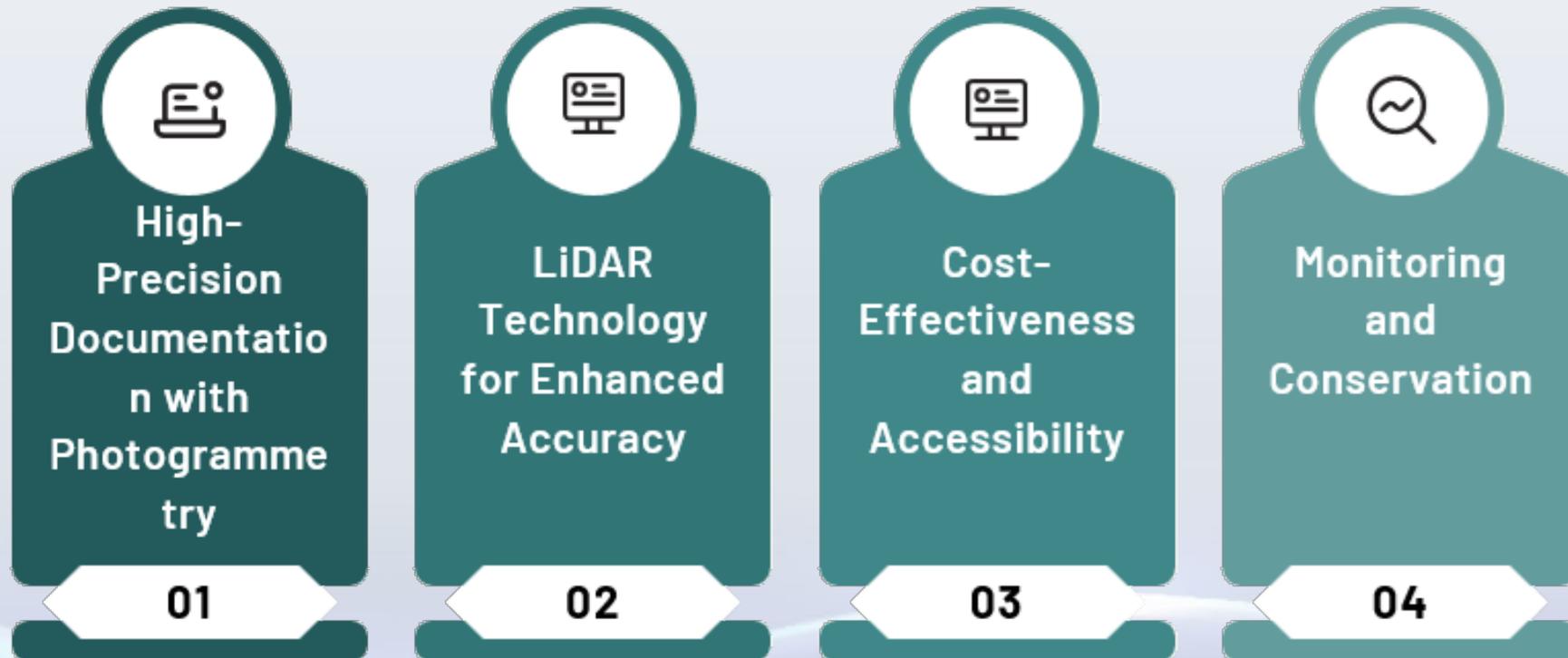
- Utilizes 3D scanning, virtual reality tours, and digital mapping.
- Creates digital records for future generations and improves accessibility.
- Protects fragile materials by reducing the need for physical handling.

Adaptive Reuse:

- Repurposes heritage sites for modern functions while preserving historical significance.
- Ensures that heritage buildings remain relevant and viable in contemporary society.

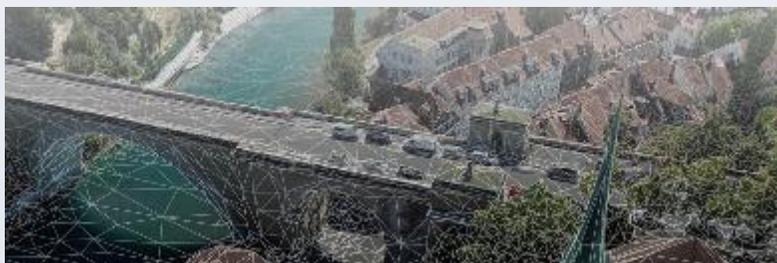
DRONE TECHNOLOGY

Drones, or Unmanned Aerial Vehicles (UAVs), have emerged as essential tools in cultural heritage preservation. They provide non-invasive, cost-effective methods to document, analyze, and preserve heritage sites. Drones, when equipped with technologies such as photogrammetry and LIDAR, allow for the creation of highly accurate 3D models of heritage sites, even in challenging terrains.



DRONE TECHNOLOGY

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METHODOLOGY OF THE STUDY PROJECT

This section outlines the study methods and approaches utilized to investigate the application of drone technology in the preservation of built heritage, specifically in the context of heritage sites.



METHODOLOGY OF THE STUDY PROJECT

Qualitative

This study adopts a qualitative approach into finding the potential of using Drones in documenting and preserving cultural heritage in Bahrain

Interviews

Data will be collected through interviews using open ended questions with participants who are involved in general building documentations in Bahrain.

The interviews were conducted via phone calls for convenience and accessibility.



Case studies

case studies will be collected on successful applications of drones in building documentation

Ethical Consideration

ethical guidelines were closely followed, including gaining informed consent and protecting participant privacy.

CASE STUDY: SANTO STEFANO CHURCH IN ITALY

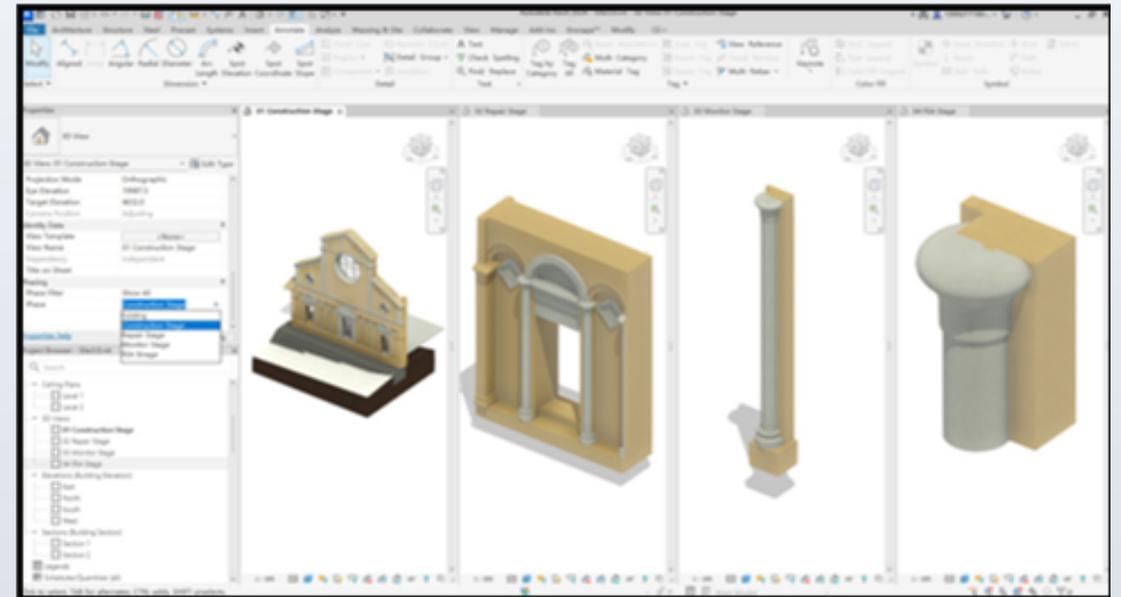
2024)

► Technological Methods

A DJI Mavic 3 Pro **drone captured 200 high-resolution images** of the Santo Stefano Church using low-altitude photogrammetry. These images were processed into detailed 3D models using **Pix4Dmapper and integrated into HBIM**, with GPS control for accuracy and VR technology for virtual restoration.

► Challenges

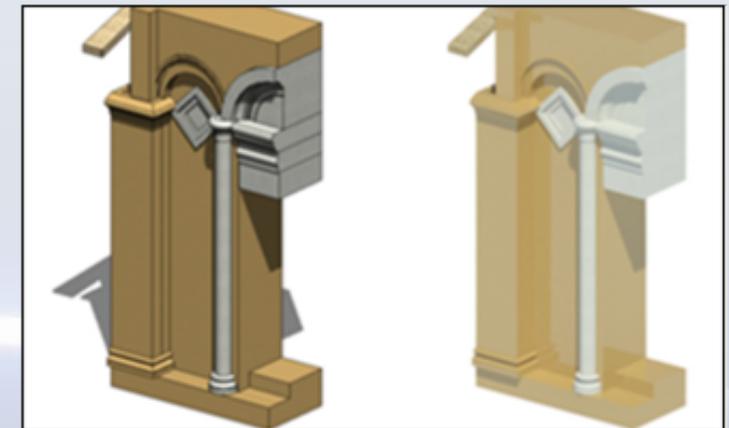
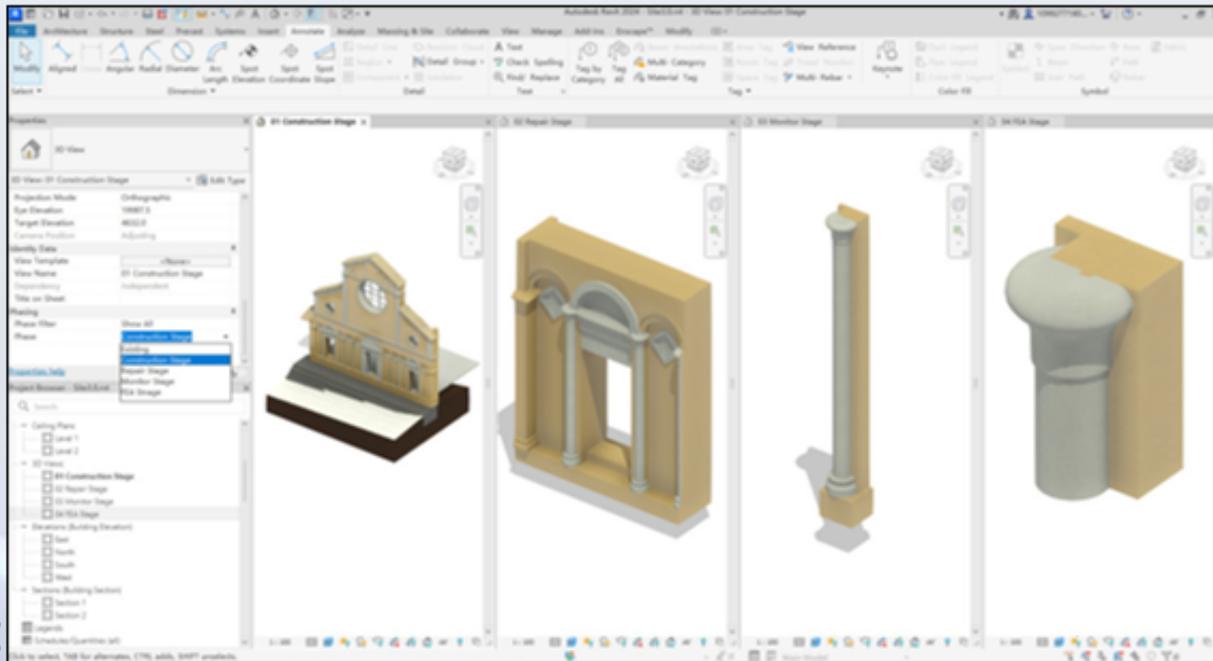
Challenges included a lack of historical documentation, **weather affecting photogrammetry**, and ensuring model accuracy, which was resolved using GPS and careful data alignment. Despite these, the project improved conservation efforts and public engagement.



CASE STUDY: SANTO STEFANO CHURCH IN ITALY

Outcomes

The project resulted in an accurate 3D point cloud, a virtual reconstruction of the church, and a family library in HBIM for heritage management. It also helped identify structural issues like wall tilting,



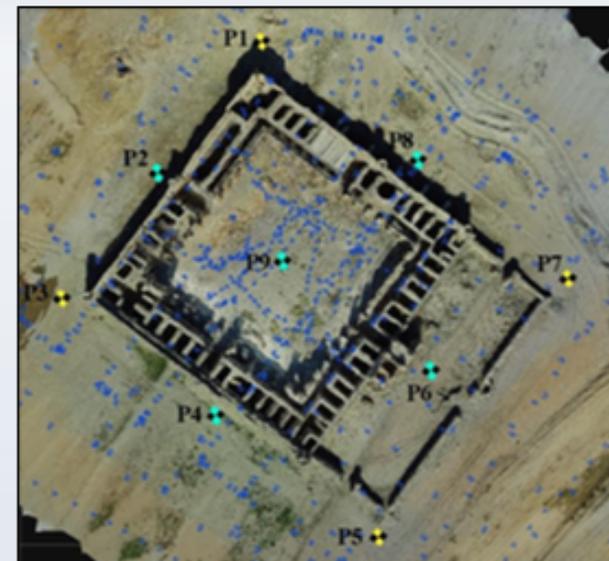
CASE STUDY: DEIR-E-KAJ CARAVANSERAI IN QOM, IRAN

► Technological Methods

- A quadcopter drone with a 12-megapixel camera and three-axis gimbal captured nadir, horizontal, and oblique images for comprehensive coverage.
- Structure from Motion (SfM) techniques in Zephyr software processed the data into a dense point cloud and 3D model.
- Ground Control Points (GCPs) were used to ensure high accuracy, achieving precision within ± 1 cm.

► Challenges

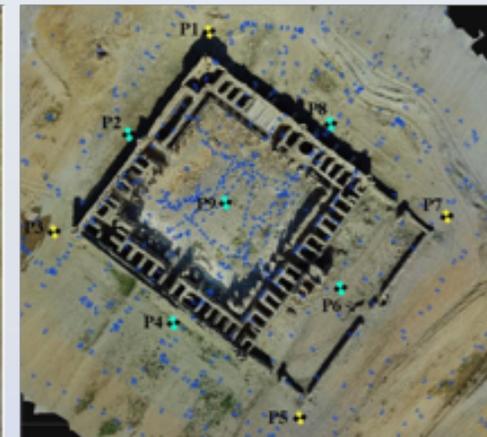
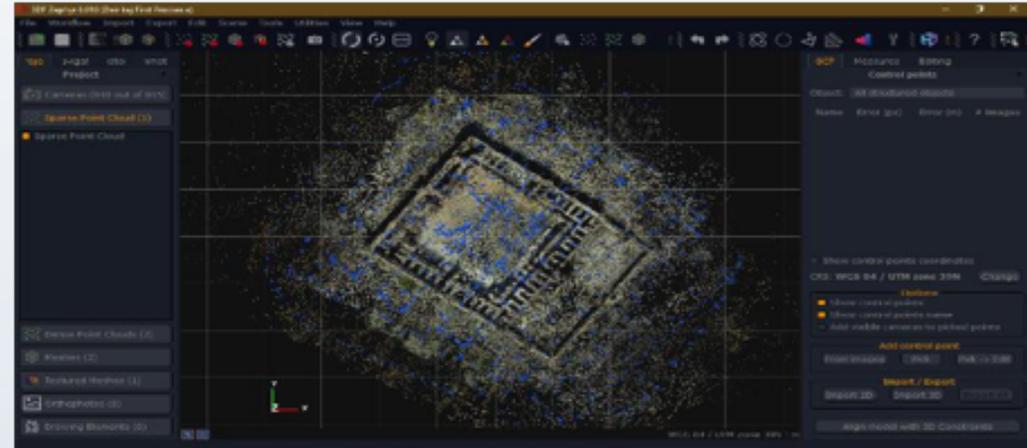
- Image coverage was challenging due to shadows and complex structures, which was mitigated by oblique imaging.
- Ensuring model precision was addressed by using GCPs and refining the accuracy through software adjustments.



CASE STUDY: DEIR-E-KAJ CARAVANSERAI IN QOM, IRAN

► Outcomes

- A highly accurate and textured 3D model was created for restoration and conservation planning.
- The multi-view imaging documented both the exterior and interior, including inaccessible areas affected by damage and illegal excavations.
- The 3D model preserved metric data for long-term research and could be integrated into GIS and virtual reality applications for public engagement.



CASE STUDY: BAHRAIN FORT

► Technological Methods

- Multi-sensor approach using UAV photogrammetry, SLAM-based mobile mapping, and terrestrial laser scanning (TLS).
- A DJI Phantom 4 Pro drone captured nadir and oblique images at various altitudes, while SLAM mapped indoor environments.
- Data was processed in Agisoft Metashape and Geoslam Hub, with Ground Control Points (GCPs) ensuring ± 2 cm accuracy.

► Challenges

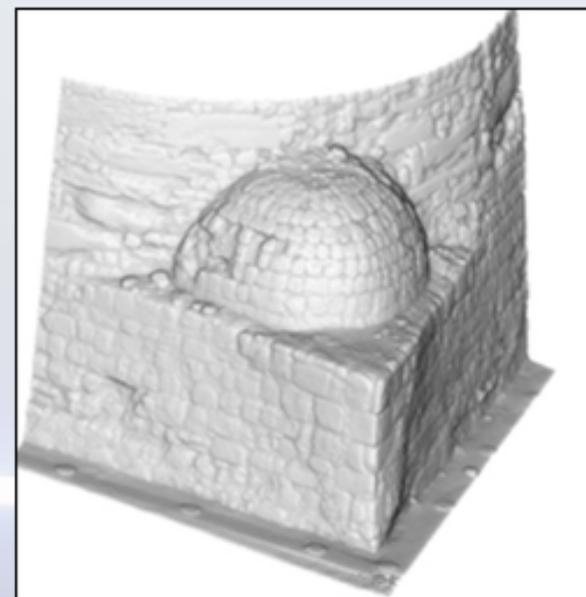
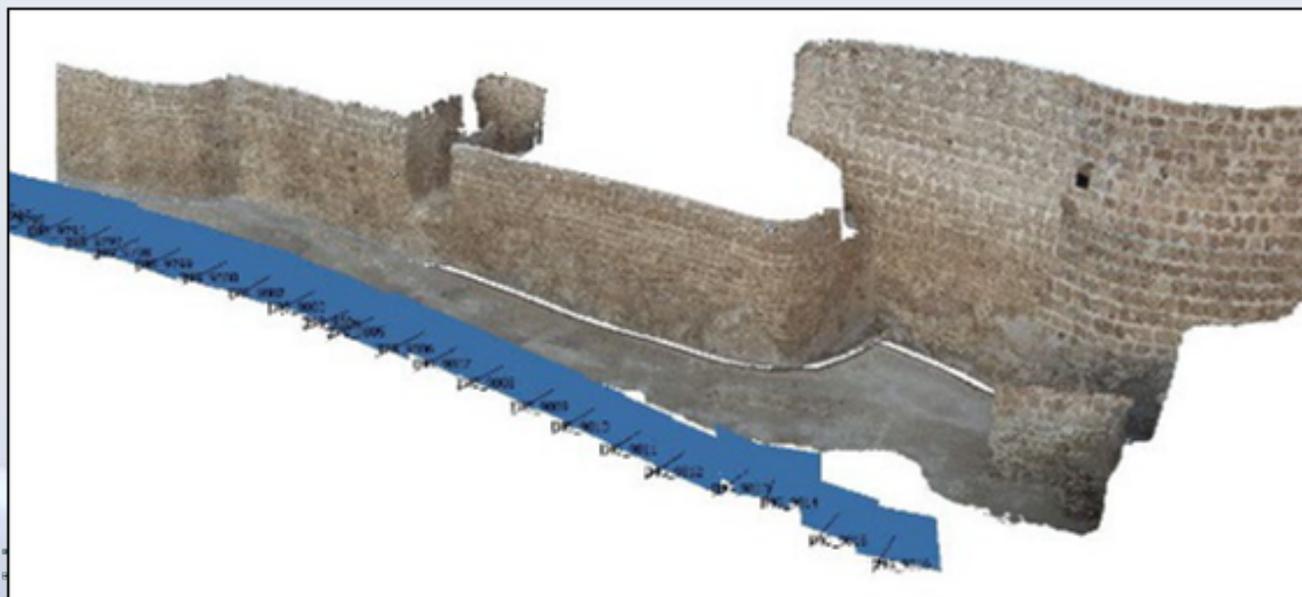
- Harsh environmental conditions, such as strong light, high temperatures, and humidity, restricted data collection times.
- Merging datasets from multiple sources presented difficulties in maintaining uniformity and accuracy across the model.



CASE STUDY: **BAHRAIN FORT**

► **Outcomes**

- highly detailed 3D model of Qal'at al-Bahrain fort was created, supporting conservation and restoration efforts.
- The model provided precise documentation of the fort's structural details and topography, aiding archaeological analysis.
- The multi-sensor approach allowed documentation of complex and inaccessible areas, with applications in virtual heritage.



DISCUSSION

In an interview with architects who work on building documentation, they highlighted the advantages of using drones in building documentation, noting their ability to capture precise 3D models and access hard-to-reach areas, such as rooftops.

However, they also pointed out challenges, such as managing large data files and dealing with privacy concerns and legal restrictions. Despite these issues, the consensus is that drones offer significant value by improving safety and providing unique perspectives that traditional methods cannot achieve.



DISCUSSION

Challenges

- Legislative restrictions and regulatory gaps.
- Public concerns:
 - Noise pollution.
 - Privacy risks.
 - Wildlife disturbance.



Opportunities

- Transformative potential in:
 - Real-time monitoring.
 - Data-driven urban planning.
 - Needs for maintenance and conservation projects.



SUMMARY OF THE DISCUSSION

Improved Accuracy and Efficiency

Drones offer precise 3D modeling and a better aerial view, surpassing traditional methods like manual mapping or laser measurements.

Access to Inaccessible Areas

Drones can document hard-to-reach locations, like rooftops or deteriorating structures, enhancing heritage documentation and safety.



Perceived Value of Drones

Despite challenges, architects agree that drones enhance safety, provide unique perspectives, and offer crucial data for restoration and site planning.

Data Management Challenges

Large and complex 3D models generated by drones can be difficult to process with existing software, leading to practical data handling issues.

Privacy and Legal Restrictions

Privacy concerns and the need for special permits, especially near sensitive locations, limit drone usage in certain areas.

CONCLUSION

Stage	Objective	Steps	Expected Outcomes	Challenges
1. Planning & Regulatory Compliance	Ensure legal and safe drone usage	<ul style="list-style-type: none">- Obtain permits from authorities- Address privacy concerns- Collaborate with government and heritage bodies	<ul style="list-style-type: none">- Legal clearance for drone use- Clear guidelines for operation	<ul style="list-style-type: none">- Delays in permit acquisition- Restricted flying areas
2. Data Acquisition	Capture detailed site data with drones	<ul style="list-style-type: none">- Use drones with photogrammetry and LiDAR- Capture inaccessible areas- Ensure safe drone operation	<ul style="list-style-type: none">- High-resolution 3D models- Comprehensive site coverage	<ul style="list-style-type: none">- Weather challenges- Large file sizes
3. Data Processing & Integration	Process and manage collected data	<ul style="list-style-type: none">- Process data with software (Pix4D, Agisoft)- Integrate data into HBIM- Optimize file sizes	<ul style="list-style-type: none">- Accurate 3D models for restoration- Detailed digital archive	<ul style="list-style-type: none">- Managing large datasets- Need for specialized expertise
4. Monitoring & Conservation	Ongoing monitoring and public engagement	<ul style="list-style-type: none">- Regular drone surveys- Real-time data feedback for conservation- Create virtual tours and simulations	<ul style="list-style-type: none">- Continuous documentation- Public engagement via virtual models	<ul style="list-style-type: none">- High operational costs- Keeping technology updated

Findings

The findings revealed that drone technology, as a digital twin concept for improving operational efficiency in Preservation Projects, significantly improves data accuracy, accelerates documentation, and offers cost-effective and engaging heritage preservation methods. In contrast, the traditional methods employed are less precise and time-consuming. The absence of different 3d shots with high-resolution images limited the depth of analysis and documenting capabilities.



The Results

The authority has to modify the strict government regulations to remove the **CRITICAL** barrier to the broader adoption of drones and limit civilian drone use.

Moreover, harmonizing preservation techniques with global standards, promoting more enduring conservation endeavors, and increasing **PUBLIC ENGAGEMENT** are mandatory.

It should be noted that the contribution of the work will be directed towards **TOURISM ACTIVITIES, STUDIES, AND LEARNING FIELDS. AND CREATE VARIOUS OPPORTUNITIES FOR NATIONAL ECONOMIC RESOURCES.**



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