USING UAVs IN DOCUMENTING CULTRUAL HERITAGE SITES - A CASE STUDY OF ZAKHO HISTORIC CITY IN KURDISTAN REGION, IRAQ

SHIREEN YOUNUS ISMAEL
Dept. of Surveying, College of Engineering, University of Duhok, Kurdistan Region – Iraq

(Received: April 25, 2021 ; Accepted for Publication: July 27, 2021)

ABSTRACT

In the Kurdistan region, despite an abundance of its cultural heritage sites and lack of majority of these sites for 3D documentation, application of Unmanned Aerial Vehicles (UAVs) for cultural heritage documentation is still in its infancy. 3D Documentation of cultural heritage sites is among the most important initial steps of developing conservation and management plans of any cultural heritage site which necessitates accuracy of the documentation.

There is lack of 3D documentation of valuable historic buildings and 3D models of historic areas that help setting guidelines for historic area development in most small cities. In contrast to that, there is a huge of infrastructure building activities carried out in the Kurdistan region since 2005, which is among one of the main reasons that have led to loss of many valuable heritage sites.

The choice of documentation technique is always dependent on the site characteristics, the required accuracy, and the main goal of documentation. Nowadays, UAVs have become a staple of documentation technology due to their accuracy, time and cost factors, as well as high abilities.

This research describes in detail the activities carried out using UAV for 3D documentation of the Zakho historic area and the Qishla historical building, which are both located in Zakho city, Kurdistan Region of Iraq (KRI). The UAV was used to collect, analyze and manage data using Agisoft Metashape Professional Software to produce point clued, orthomosaic, digital elevation model, and 3D models for the two sites.

Finally, this paper discusses the potential of UAVs for cultural heritage site documentation in the context of KRI and how the advantages of this technology be gained before further loss of the richness and details of the cultural heritage sites.

***KEYWORDS*:** UAVs, 3D Documentation, Zakho Historical Area, Qishla Building, Kurdistan Region

INTRODUCTION

Recently, Unmanned Aerial Vehicles (UAVs) have taken a civil role despite being initially made for military purposes. The civil applications are becoming more and more diverse over time, with UAVs being used for disaster management, hydrographic maps, advancing transportation systems (safety and traffic monitoring), etc.

The application spectrum for UAVs is widening with time due to the ability to combine UAVs with other technologies and tools, continuous development of computer software and hardware application, ease of data acquisition, low cost, increased mobility in hard-to-reach areas, etc. UAVs have been developed in stages; the broad spectrum of applications of these drones has received most attention which led to the invention of various types of drones with different sizes and weights.

However, heritage is not an inaccessible field to the application of the UAV technology (Murtiyoso and Grussenmeyer, 2017), which can particularly benefit heritage, to a large extent, in 3D documentation, monitoring, and presentation of heritage sites (Yastikli, 2007), in addition to maintenance and conservation activities (Bruno and Roncella, 2018).

Cultural heritage site 3D documentation is an essential activity (Murtiyoso and Grussenmeyer, 2017) to develop conservation and management plan for any cultural heritage site including historic area, historical building, archaeological structure and ruins. Having a detailed 3D model is necessary for further analysis and interpretation of the site (Barsanti et al., 2014 in Murtiyoso and Grussenmeyer, 2017). Meanwhile, the accuracy of 3D documentation is fundamental as it represents the main input of the valorization process of the sites and subsequent development of the conservation and management plans of the sites.

Photogrammetry is concerned with deriving measurements of the size, shape, position and texture of objects from measurements made on photographs; after which3D models are created through overlapping images with camera position and orientation information. Traditional photogrammetry has a long history in cultural heritage site documentation (Al-Ruzouq, 2012; Yastikli, 2007). However, 3D models attained using classical terrestrial-based acquisition methods require stereoscopic skills, which leads to traditional photogrammetry being very complex in data processing, time-consuming and labor-intensive (Themistocleous, 2019) which make it difficult to become the mainstream technology for mapping (Wang et al., 2019).

Today, innovative systems have been developed for cultural heritage sites documentation, such as digital photogrammetry and terrestrial laser scanning (Yastikli, 2007). The latter is used to collect data when very high accuracy levels are required (up to 2 millimeters) (Kilby and Kilby 2018). Laser scanners are fast and efficient in 3D modeling of cultural sites (Yastikli, 2007) and can be used in small to medium areas (Korumaz et al., 2014; Yastikli, 2007). However, a drawback of laser-scanning is the very high cost of its deployment.

Digital photogrammetry has evolved over time due to the introduction of simplified digital tools (e.g., digital cameras, computers, information systems), computer software, and improvement of matching algorithms that easily permit 3D model reconstruction (Girelli et al., 2005). Various methods, such as digital image rectification, monographic multi-image evaluation, stereo digital photogrammetry, and ortho-imagery, are used in digital photogrammetry software system according to the specific characteristics or needs of the cultural heritage sites (Yastikli, 2007). However, UAVs equipped with digital cameras, can be used for low-altitude imaging, and are nowadays becoming an alternative remote sensing of spatial data method (Themistocleous, 2019). Hence, this technology has become a very important and consistent method for documentation of cultural heritage sites (Kilby and Kilby 2018), making UAVs a particularly sustainable approach to documentation of cultural heritage sites due to its affordability, reliability, and straightforward method of capturing heritage sites (Themistocleous, 2019; Girelli et al., 2005).

Aerial imagery from UAVs provides data with high spatial resolution and high temporal frequencies over large area, and allows rapid generation of 3D digital surface models for documentation and model reconstruction (Girelli et al., 2005). This is always the result of image processing conducted using Photogrammetry software (Themistocleous, 2019), Which enables documentation process to include both the site and its cultural landscape in which ancient vestiges are located. (Themistocleous, 2019).

The accuracy of a UAV platform is attributed to its cameras or sensors. UAVs can be equipped with numerous sensors, such as visible spectrum, thermal, infrared, and other multispectral cameras (Themistocleous et al., 2014). The numerous sensors in a UAV give valuable information for further analysis and data interpretation (Korumaz et al., 2014) Thus, UAVs have become even more useful in excavations, restoration, and observation of the sites (Sauerbier and Eisenbeiss, 2010 in Wang et al., 2019; Murtiyoso and Grussenmeyer, 2017). Watanable and Kawahara (2016) demonstrates the application of aerial photographs for large scale, complex site and archaeology site (Wang et al., 2019),

Since UAVs are a broad category, there are many different types of UAVs in use. The first type of UAVs used is the balloon or kite, which was lighter-than-air platforms and very low-cost, but had very low air resistance. It was first used in archaeological documentation in 1967 by Whittlesey (Eisenbeiss, 2009 in Korumaz et al., 2014). Another type of UAVs is the fixed-wing platform, which is suited for large-scale mapping, but provides little payload. The last type of UAVs is the rotary-wing platform, which has high wind resistance and payload, but much lower surface coverage than fixed-wing platforms. UAVs constantly evolve and these categories see constant development and innovation. The choice of UAV types is dependent on many factors, such as required accuracy and site characteristics like size, the main aim of 3D documentation and other site limitations (Themistocleous, 2019).

New-generation of UAVs have evolved in battery size, function, camera control, and remote control, thus enabling them to be conveniently used with mobile devices with flight times exceeding 30 minutes (Kilby and Kilby 2018). Moreover, cameras and sensors are decreasing in size to fit ever-evolving UAV systems. The potentials of UAVs in terms of being remotely controlled, having less cost time for data collection and high accuracy of data, lead them to be quite often used in dangerous sites (Korumaz et al., 2014; Alsadik, 2020), such as sites that are at risk of demolition, negligence, or improper preservation (International Council on Monuments and Sites, 2014).

Nevertheless, UAVs should not be considered a sole solution to documentation challenges, and other sources of data documentation must not be ignored especially when what exist on the site are only ruins. Such data include written records from local historians, panoramic photography, normal photos, and state archaeological surveys. All of them could be used interestedly with the UAVs images in order to obtain accurate documentation and visualize the site in a way that had not previously been possible (Kilby and Kilby, 2018).

In Iraq, including the Kurdistan region, there are tens of thousands of heritage sites, both registered and unregistered. 3D documentation of Iraqi sites has been very limited due to numerous factors, such as site accessibility difficulties, lack of proper experience in 3D documentation or security, community negligence, the sheer number of sites in the country, and existing limits on budget and resources (Alsadik, 2020). However, there have been efforts made recently by international organizations and experts to excavate small areas with laser-scanning technology, Prof. Daniele Morandli Bonacossi for Khinnis site in Duhok province (Duhok General Directorate of Antiquities, 2020). As for local initiatives, useful research has been done by local researchers for digital documentation of cultural heritage sites in the Kurdistan region, such as the historical buildings in Erbil Citadel where smartphones and compact cameras were used for documentation (Sadeq, 2018). Furthermore, laser-scanning has also been used by local researchers for documenting historical buildings in Erbil Citadel (Mala et al. 2019).

However, a basic initiative by ICONEM started in 2016 for the use of drones in 3D modelling for heritage sites in Iraq, specifically heritage sites at risk of demolition. In Erbil, the initiative included educational training on UAV usage for local archaeologists as part of a UNESCO project in Iraq. Around 10 sites were included in the initiative of 3D modeling, such as Amedy city, the Akre synagogue, and Halameta Cave in Duhok province, yet the local government hasn't received the results due to limited funding. In 2018 UAVs have also been used to address the cultural landscape around an archaeological site, such as Dr. Peter Pfaelzner for Bassetki site in Duhok province (Duhok General Directorate of Antiquities, 2020).

The Kurdistan region in particular was intentionally excluded from the heritage activities including surveying and documentation, excavation, and conservation of the sites, for much of its recent history (Ismael, 2015). Nonetheless, when the reconstruction efforts started all over Iraq after 2005, the Kurdistan region has experienced huge sprawl as part of an infrastructure development plan. Yet, this process phenomenon leads to the erosion of many cultural heritage sites, specifically in the historical areas of cities in Duhok Governorate such as Amedy, Akre, Zakho, and Duhok (Ismael, 2015). It has also caused loss in valuable information about the historical buildings and areas, which has hindered their documentation. Kurdistan is characterized with mountainous landscape; a large number of heritage sites, are situated in areas that are hard to access, such as small castles on hilltops, churches in rough terrain mainly in the rural areas, historical areas in relatively inaccessible edges of cities especially in regards to hilltop cities like Amedy, small isles like Zakho historic area, and buildings on steep hillsides in terrace form in the historical city of Akre.

From 2009 until 2013, many master plans were formulated for the cities in Duhok Governorate, such as Duhok, Zakho, Akre, Amedy, and many other small towns. The master plan reports have identified historic areas of the cities and recommended protection and setting guidelines for the development of those specific areas for integration with the general master plans of the cities (Duhok Directorate of Constructive Planning, 2021).

Guidelines for the historic area development is among the main recommendations of United Nations Educational, Scientific and Cultural organization (UNESCO) and is also emphasized in the Iraqi Heritage Law no. 55 of 2002. These guidelines are used to preserve the most ancient urban pattern from changes, control the building height to organize the skyline, to keep the view without disturbance from and to the valuable sites, manage easy access to the sites, organize the land use patterns around the sites, to promote the vernacular architecture style, etc. Nevertheless, no guidelines have been made yet for the historic areas which could have been made easy with the 3D documentation of these sites. This has led to many sites losing their significance, such as the buildings in Akre historic area that form terrace shape of the city which has been completely neglected and close to being lost (Ismael, 2015). It is to be noted that the historical area in Akre city is registered as one heritage site in the national inventory known as *Atlas of Archaeological Sites in Iraq* which was published by the (Ministry of Culture and Information of the Republic of Iraq, Iraq Directorate General of Antiquities, 1970). In addition, most of the historical buildings and monuments in Amedy and Zakho cities particularly in the Jewish quarter have been replaced by new buildings without documentation. Many of those remaining sites have been obscured by higher buildings and are currently in a very poor state.

Primarily due to the fact that UAVs in Iraq, including the Kurdistan region, are used primarily for military purposes and operations against the Islamic State of Iraq and Syria (ISIS) terrorist activities, or for media purposes. Permission for use of UVAs for the cultural sites in the disputed areas between the Federal Iraq Government and KRG must be granted by the security authorities in both governments. This is why this study, which was initially intended for Alqosh historical city, was relocated to Zakho historic area to avoid additional administrative obstacles. Alqosh is located in Ninewa Plains and a disputed area which is administratively under the jurisdiction of the Iraqi government and security wise under KRG.

The aim of this paper is to gain a better understanding of UAV application in cultural heritage in the context of the Kurdistan region, and the suitability of this method for the context, in terms of nature, current situation and the needs of cultural heritage sites, and present the methodology of producing 3D models using the historic area of Zakho City as an example, along with the 3D surface model of Qishla historic building.

Study area:

Zakho city is located in the northern part of Duhok province in the Kurdistan Region of Iraq (Figure 1 A). It is only 10 kilometers far from the border with Turkey, and 25 kilometers from the border with

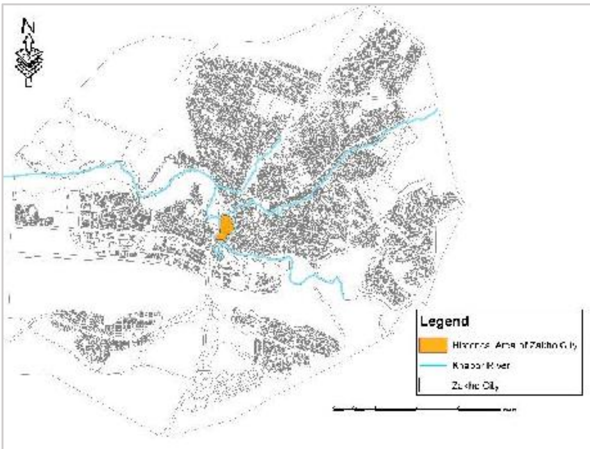

Fig.(1):-A: Zakho City in the Context of Kurdistan Auther,2021 egion – Iraq Source: KRG, 2008

Fig.(1):-B: Historical Area of Zakho Cit Source: Auther,2021

Syria (Al-Jafi, 2021). It is currently populated by approximately 200,000 inhabitants.

Since Zakho district is a part of Mesopotamia, 115 sites of different civilizations are registered as archeological sites; 10 of those are located in Zakho city (Zakho Directorate of Antiquities, 2021). The historical area of the city is a small isle surrounded by Khabur river (Figure 1 B), which is one of the main tributaries of the Tigris river. Historically, Khabur River had great impact on the economy of the region for transportation of commercial convoys to the neighboring areas (Rasheed and Abdulkarim, 2017).

Zakho city had always been ethnically diverse including Jews, Muslims, Christians, Yezidis, and other groups as residents which has been reflected in the structure of the historic area of the city for centuries. The historical area in this city consists of two quarters separated by the historical bazaar: the Jewish quarter, which is located in the northern part of the isle and was populated by Jews, and the Rita quarter, which is located in the southern part and was populated mainly by Muslims. The historical area also included many bridges connecting the isle with its surroundings. The buildings and the bridges were constructed of stone and lime. One of the most important and still existing bridges - Pira Dalal - is listed as a Roman historical bridge (O'Connor, 1993).

Zakho historic city had many prominent buildings, and two landmarks in particular were significant in Zakho's history: The first is the Qishla building, which was originally constructed as a castle that has later been used as an administrative building; in fact, it was the largest building in the historical city. The first mention to the building dates back to the 11th century (Zakho Directorate of Antiquities, 2021). The longest façade of the building is directly situated on the Khabur River, and the building could be recognized from far away. Today, the Qishla building is partially demolished and the remaining part is occupied by the Archaeological Directory. Despite its historical and architectural value, no digital documentation has been made for it. The second landmark is the synagogue, of which only the ruins remain. It has never been documented, and the only data available for it are photos from the 1950s.

Currently, most of the historic buildings in the Jewish quarter and in historic bazar are in poor conditions, while a slight number is in fair conditions. Furthermore, changes, either permitted or not, are continuously happening around those buildings thus affecting their access, view, traditional integrity, and skyline. Moreover, the municipality of Zakho is under the pressure of fulfilling many different requests for building permissions from homeowners, specifically in the Jewish Quarter and the historic bazaar of the city. The requests also include replacement of the old buildings with new construction or adding more floors to the existing buildings, etc.

Since the municipality has no guidelines on historic area development, a conflict between the desires of the local people and the municipality is present. The municipality is thus in need of 2D site documentation and 3D models of the historic area of the city to set guidelines for integrating the historical area with the general master plan of the city which was mainly based on satellite images.

METHODS

This part explains how UAVs were used to acquire aerial images of the historic isle of Zakho city and document the Qishla historical building. All the required flight permissions were obtained from the security authorities (Asayish) in Duhok governorate and Zakho city. To collect data, DJI Phantom 4 Pro UAV, equipped with camera (DJI 1"CMOS Effective per pixels: 20M) was used in this study for recording images. Image processing was conducted by photogrammetry using Agisoft Metashape Professional Software to create 3D models and produce an orthomosaic and DEM image for the historic area and 3D surface models for Qishal building.

Planning the UAV Flight: area

To start image capturing, a careful plan of UAV flight is a fundamental task because of technical limitations, used equipment and sensors, and characteristics of each site (Manajitprasert et. al., 2019). Therefore, having an observation visit to the site or access to the area maps is necessary, as this will help gain information about the site in terms of the area size, and navigate the complexity in the area to understand nature of the obstacles that need to be avoided (Kilby and Kilby, 2018) and to identify locations where Ground Control Points (GCPs) could be placed. Initial takeoff, landing point and direction of the first strip also have to be planned carefully, especially in dense urban areas as the case with the study area.

The plan should also include the flight path and number of the strips that need to be properly planned and controlled. The size of the study area and the required accuracy need to be considered while identifying the flight altitude. In the case study, Map Pilot for DJI Business software was used to manage the flight altitude.

GCP's establishment

Thirteen GCPs were distributed covering the whole historical part of the city of those two (GCP7 and GCP13) were used as check points (Figure 2). The GCPs were placed on a limited vacant area within the historical area, such as the open space in the northern part of the Jewish quarter, on the alleys close to the exterior edge of the historic area, and on the median of the main street that crosses the historical area, to ensure that GCPs are covering all the study area. Differential GPS (DGPS) with Real Time Kinematic method were used to setup the GCPs, which were then spray-painted with large crosses to be visible from long distances.

GCPs are used to correct positioning of the UAV platform and allow for selection of a sub-set of images on key sites in the study area in case the need arises for more details (Themistocleous, 2019). This is a very important step if the plan involves specific analysis for historical buildings either in the old bazar, or historical residential buildings within the old quarters. It helps obtaining more details about those buildings such as current physical condition, the nature of changes around, and access to the sites, etc.

The number and spatial distribution of GCPs are very important for the accuracy of the 3D model. It is demonstrated that using medium number of GCPs (3 GCPs for 50 Images) to large number of GCPs (3 GCPs per35 images), high accuracy can be achieved (Sanz-Ablanedo et al., 2018).

Fig.(2): -Location of 13 GCPs and 2 check points Marking

<u>Data Acquisition and Processing of Zakho Historic Area</u>

In 25th of January. 2021 Acquiring low-level aerial imagery, the roof of the Zakho municipality building was used for Initial takeoff and landing point of the drone. DJI Phantom 4 Pro UAV equipped with camera type (DJI 1"CMOS Effective pixels: 20M.) flown a pre-programmed route, performed in (12 strips) west-east (Figure 3). The flight path was managed using Map Pilot for DJI Business software. The GSD (Ground Sample Distance) is

2.18 cm/pix. Camera calibration been done before the flight, following the steps below;

1- Connecting drone to PC. 2- Opening up the DJI Assistant application. The model of the drone will appear when connected to the PC. 3- After clicking on the drone file within DJI Assistant, click calibration on the left bar of the application. 4- Click on "Start Calibration". 5- Positioning the sensors of the drone in front of the computer screen such that the corners of the red boxes coincide with the blue boxes. 6- Calibrating vertical and horizontal movement. 7- Flipping the drone so that the bottom of the drone faces the screen for bottom sensor calibration. 8- Lining the sensors up with the blue boxes again, and then calibrating vertical and horizontal movement again. 9- Calibration settings are then automatically adjusted.

Fig. (3):- Flight Path in Mission

The total of (366 images) were captured with an overlap of (80% Front and 75% Side). The flight was planned by using the offline platform (DJI FPV Radio remote controller mode 2), A 31 minutes flight was needed to survey 0.16 km2 of the study area.

was used to conduct the image processing, this software is capable of interpolation digital images that helps creation high-resolution, scaled, and geo-referenced 3D models from acquired images (Themistocleous, 2019). Before photo alignment process, PhotoModeler program used to introduce and integrate the camera calibration information with Agisoft Metashape Professional Software as shown in Table 1.

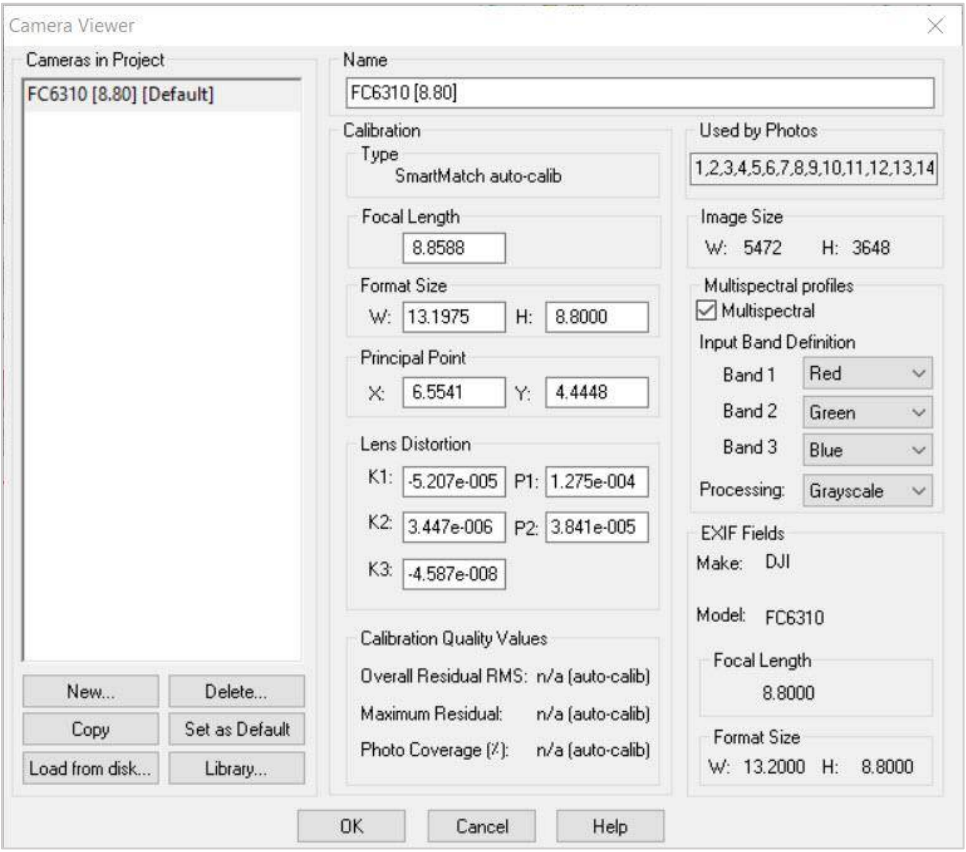

Table (1): -Camera Calibration Information

All images (366) were taken from the height of (86.9 m) and were included in the processing using (SfM) Structure from Motion photogrammetric method, in order to create a rapid and automated generation of a dense point cloud of the historic area, this is after the software automatically excluded the background of the images throughout the photo alignment process and produce a less noisy point cloud (Themistocleous, 2019) (Figure 4), the remaining number of images were 261 images according to the Agisoft program report. However, the procedure is encompass the production of a 2.29 cm per pixel orthomosaic from multiple images (Figure 5), which was used to create 3D model later on (Figure 6) and produced a 9.17 cm per pixel digital elevation model (Figure 7). To complete the geo-referencing, Leica Viva DGPS GS10 Base with GS15 Rover with Real Time Kinematic survey method and WGS 84 / UTM zone 38N / EGM2008 Coordinate system were used.

Fig.(4): -Dense Point Cloud of Zakho Historic Area

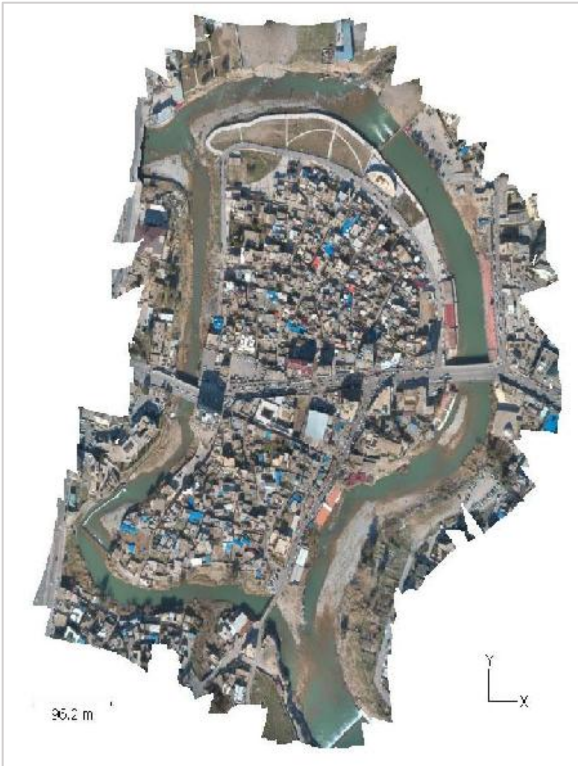

Fig.(5): -Orthomosaic of Zakho Historic Area

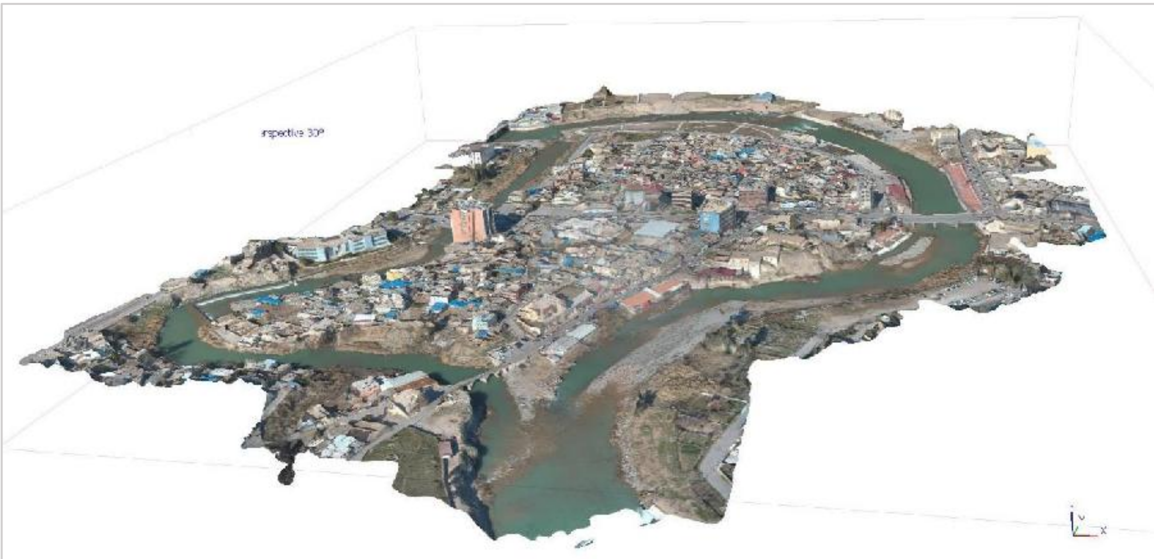

Fig.(6):- 3D Model of Zakho Historic Area

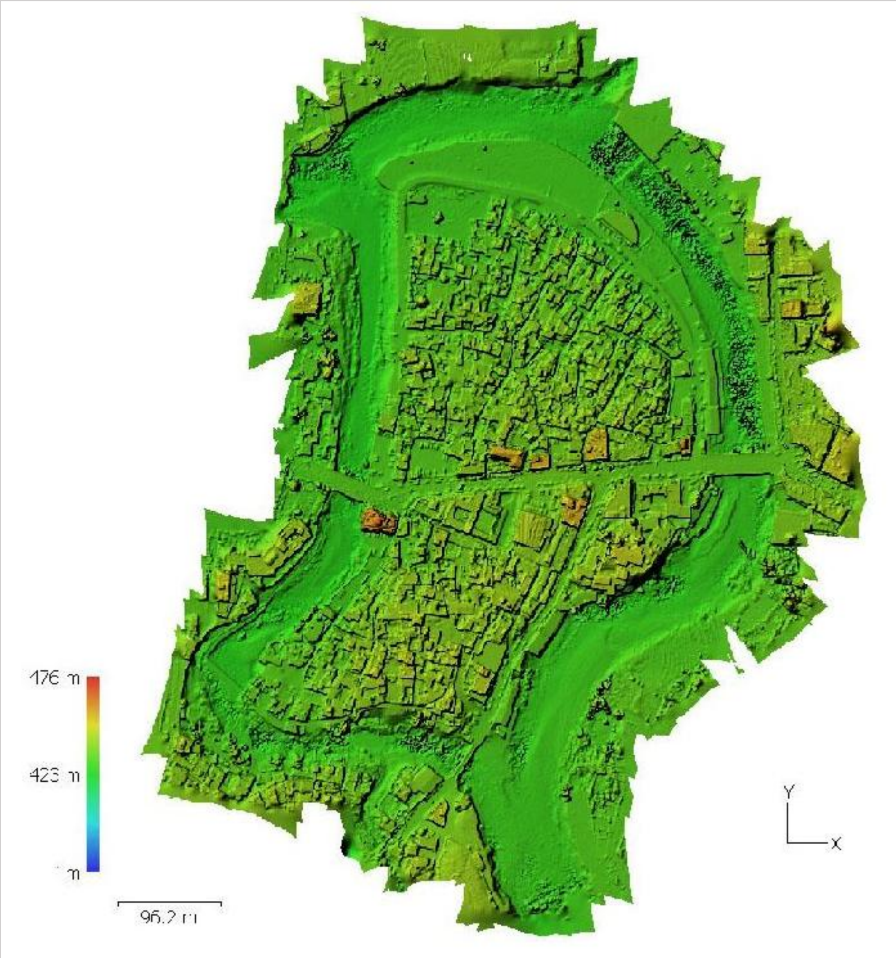

Fig.(7):- DEM of Zakho Historic Area (Resolution 9.17cm/pix)

The total value of RMSE (Root Mean Square Error) of the 11GCPs that were used along with 2 check points, 7 and 13, was 2.6179 cm as shown in Table 2. The highest error value was for the check point 13 as it was 5.09523 cm according to the Agisoft program report.

Table (2):- Control Points RMSE

Count points	Error X (cm)	Error Y (cm)	Error Z (cm)	Error XY (cm)	Total (cm)
13	0.716627	1.19011	2.21889	1.38921	2.6179

X-Easting Y- Northing Z- Altitude

Sanz-Ablanedo et al. (2018) discussed different methods that could be applied to evaluate the accuracy of the geo-referenced SfM -3D model. Using RMSE-3D for the check points to evaluate the accuracy is more objective and reliable than using total RMSE-3D for all GCPs. The high accuracy represent achieved if RMSE-3D at check points is < ± 2 × GSD of the project or the Horizontal RMSE of check points is 1.2 × GSD and Vertical RMSE is 2 × GSD. The Horizontal RMSE could reach the similar value of GSD, while with Vertical RMSE is not possible.

The RMSE-3D for the check points 7 and 13 for the study area was 4.59 as shown in Table 3. The value of 2 × GSD is 4.36, this means that RMSE-3D value is slightly higher than 2 × GSD value. This indicates

that the accuracy is considered high. Moreover, the horizontal RMSE of check points is 2.441 which is slightly less than 1.2 × GSD. Furthermore, the vertical RMSE of checkpoints is 3.89 which is less than 2 × GSD as shown in Table 4 and 5 respectively.

Table (3): -Total RMSE-3D of Check Points

Check points	Error X (cm)	Error Y(cm)	Error Z (cm)	Error XYZ (cm)	Total RMSE-3D of Check Points
GCP7	0.286842	-1.65694	-3.66184	4.02949	4.59
GCP13	1.35096	2.69563	4.1073	5.09523	

Table (4):- Horizontal RMSE of Check Points

Check points	Error X (cm)	Error Y (cm)	Horizontal RMSE of Check Points
GCP7	0.286842	-1.65694	2.441
GCP13	1.35096	2.69563	
Total	0.97656	2.23739	

Table(5): -Vertical RMSE of Check Points

Check points	Z error (cm)	Vertical RMSE of Check Points
GCP7	-3.66184	3.89
GCP13	4.1073	

Results obtained through using the related equations below which were obtained from many references, including (Azmi et al. 2014):

Total RMSE = $\sqrt{\frac{1}{n}\sum_{i=i}^{n} Error\ XYZ_i^2}$ Error XYZ i = $\sqrt{ErrorX_i^2 + ErrorY_i^2 + ErrorZ_i^2}$

n- Is the total number of GCPs

Horizontal RMSE = $\sqrt{(\text{RMSE } x)^{\mathbf{2}} + (\text{RMSE } y)^{\mathbf{2}}}$

RMSE x = $\sqrt{\frac{1}{n}\sum_{i=i}^{n} Error\ X_i^2}$ RMSE y = $\sqrt{\frac{1}{n}\sum_{i=i}^{n} Error\ Y_i^2}$

Vertical RMSE

RMSE z = $\sqrt{\frac{1}{n}\sum_{i=i}^{n} Error\ Z_i^2}$

Data Acquisition and Processing of Qishla Building:

Qishla building is a very important historical building in the city, but it still remains witout digital documentation. It was constructed in several parts with different heights on a big rock, with the longest façade directly on the Khabur River east of the city, Generally, this building has no regular height and

shape; its skyline ranges between one to three floors, with the last floor lacking the roof and parts of the walls. The Qishla is surrounded by new buildings at the north and the south, and by a new 5-floor building with a narrow busy road in between at the west.

In order to have more information and accurate data about the Qishla building, the second flight of the same UAV (DJI Phantom 4 Pro UAV equipped with camera type (DJI FC6310 8.8mm) was used on 13/02/2021. Within a period of 10 minutes and 20 seconds, a total of121 images were captured with overlap (80% Front and 75% Side) from a manually planned flight with height 31.7 m, performed in two circular strips around the building. The plan was originally to fly the UAV in automatic mode, however, the researcher was unable to fly the drone automatically as Zakho is close to the operation zone for recent Turkish military strikes near the border. Other research groups in New Zakho (an area in Zakho city) and Amedy city were also unable to operate their UAVs for the same reason. Therefore, the drone was flown in manual mode to capture all necessary images and to avoid the physical obstacles around the Qishla building. Such obstacles include existence of high buildings, trees, and dangling wires of rom private electricity generators as standby power sources when electricity from te national grid is off. Those obstacles affected the flight plan which led to having regular distances between the camera capturing locations and the building. However, most of the images were taken from a distance of 2 to 2.6 m, and to have more accurate 3D surface models, 10 check points were used as shown in Figure 8.

Fig.(8): -10 Checkpoints for Qishla Building

All images were included in processing using Agisoft Metashape Professional Software version1.5.2.7838) to generate a dense point cloud of the Qishla building (Figure 9), the images processed using SfM method to align images and building points clouds.

Fig.(9):- Point Clouds of Qishla Building

The software automatically produced a 8.29 mm per pixel orthomosaic and a 3.31 cm per pixel digital elevation model (Figure 10 and Figure 11) in order to create accurate 3D model, 10 check points been applied (Figure12 A and B).

Fig.(10):- Orthomosaic of Qishla Building

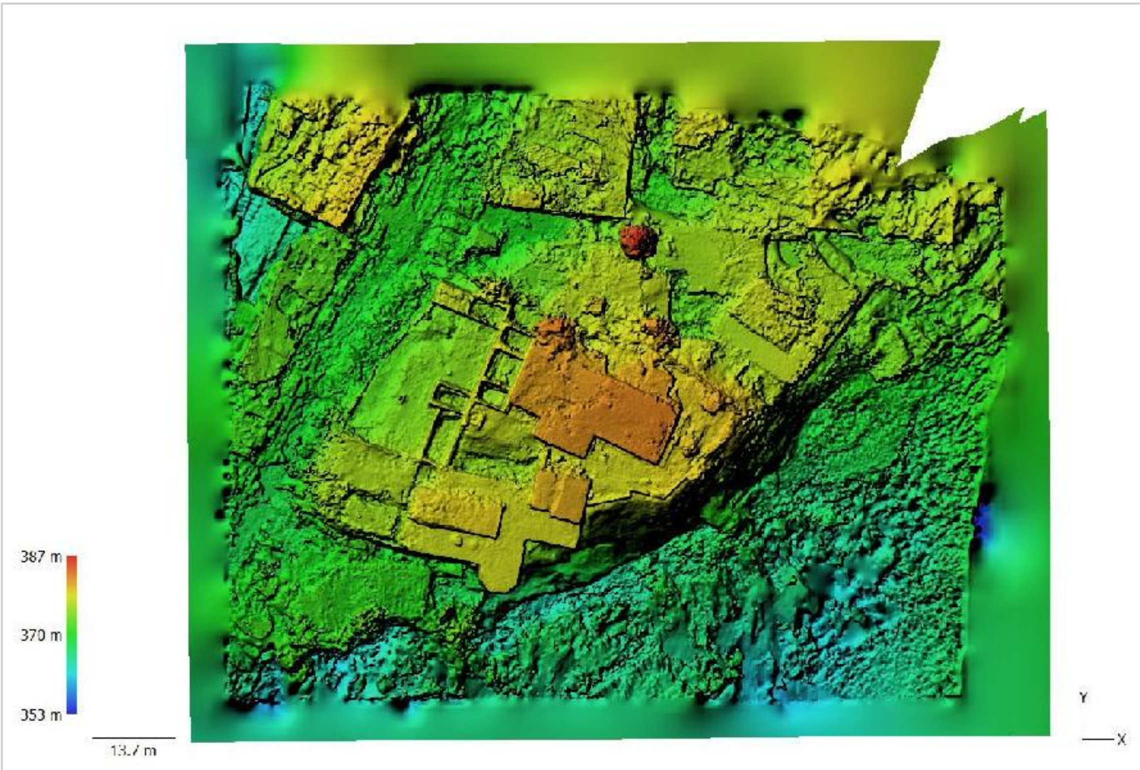

Fig.(11):- Digital Elevation Model of Qishla Building (Resolution 3.31cm/pix)

Fig.(12):-A: 3D Model of Qishla Building from West Side (Old Bazar)

Fig.(12):-B: 3D Model of Qishla Building from East Side (Khabour River)

Regarding the RMSE of the 10 check points been applied, the total of error estimation was (1.19522 m) as shown in Table 6 .

Table (6):- Control Points RMSE of Qishla Historic Building

Count points	Error X (m)	Error Y (m)	Error Z(m)	ErrorXY (m)	Total(m)
10	0.843078	o.715011	0.454448	1.10545	1.19522

X-Easting Y- Northing Z- Altitude

Moreover, the comparison between the dimensions of the obtained model of Qishla historic building from the program with actual dimensions from the western façade of the building has been conducted, the result could be seen in Table 7. The total value of the error is

0.598163 m. The highest error values are in the scale bars (point9-point10) and (point3-point4). However, the building is huge, but has no many architectural details and inscriptions in the façade. Therefore, such accuracy is fine for maintenance work.

Table(7):- Control Scale Bars of Qishal Historic Building

Label	Distance (m)by Program	Actual Distance (m)	Error (m)
Point 1 - Point 2	3.96151	4.4	-0.48493
Point 3 - Point 4	13.6782	14.0	-0.761833
Point 5 - Point 6	2.99278	3.0	-0.00722325
Point 7 - Point 8	10.5882	10.94	-0.351768
Point 9 - Point 10	4.94474	4.0	0.94474
Total			**0.598163**

DISCUSSION

UAVs are helpful to assist architects, archaeologists, and urban planners to manage the sites. UAV images are more useful than satellite imagery, as they produce more accurate 3D model with the use of GCPs and provide more information that is needed for setting guidelines for the historic area.

The RMSE-3D for both check points 7 and 13 was 4.59 which is slightly higher than 2x GSD. This indicates that the accuracy of the 3D model is considered high. This means the model of the Zakho historic area is quite useful for setting guidelines such as skyline, viewpoints, improvement the access, etc… and developing a specific master plan of Zakho historic area to be integrated with the general master plan of the city later on.

However, the number of GCPs used for the study area was relatively high 3 for 100 images, and they have been distributed within the study area. GCPs placement in the Jewish quarter was the most challenging step, since it has an organic urban pattern, consist of dense and small houses connected by narrow and zigzag paths, without open spaces.

However, There are many other factors affecting the accuracy, such as the geometric distribution of the GCPs, the overlap between the flight line, camera calibration approaches s, etc. Calculating the accuracy of the model produced by UAVs is a subject that require more research.

If a significant or valuable site (building) has many details and needs specific guidelines to control the changes around or to guide conservation and maintenance work, another flight could be planned with lower height in order to capture more accurate images and help provide more information, particularly if the UAV camera is positioned vertical and closer to the building façade (Korumaz et al., 2014).

The surroundings of the Qishla building consist of immovable obstacles such as buildings and trees and partially movable obstacles such as electric power lines. These obstacles shows the importance of having coordination with other departments of administration such as electricity, not just security, in order to obtain more accurate imagery.

The dimensions of Qishla historic building model obtained from the program have been compared with actual dimensions of the building using 5 scale bars, the total error value was 0.598163 m. Such accuracy could be fine for the maintenance work since the building doesn’t has many architectural details or inscriptions in the façade. However, the researchers recommend another flight, this time in automatic mode, to be conducted for Qishla historic building after Turkish military operations subside that considers partially movable obstacles as well. As much as the total error is less, as much as benefits could be gained from the generated point cloud form UAV.

CONCLUSION

The importance of UAVs in cultural heritage site documentation has been acknowledged by researchers and professionals to some extent in different contexts. However, in the study context, the potential of UAVs has not been clarified and discussed yet. There are thousands of sites in the Kurdistan region that have not been documented, and are at continuous risk of destruction due to neglect and mismanagement, particularly in the urban areas. In this paper, the benefits of UAVs have been reviewed, especially in regards to their low cost, time-efficiency, mobility in inaccessible areas, and data collection ability. Cultural heritage sites including archeological sites, and historical areas and buildings in the Kurdistan region are often located in relatively inaccessible areas, making the use of UAVs a key to heritage documentation.

Current efforts by international initiatives in 3D modeling for heritage sites are inadequate in addressing the heritage conservation needs of the region at the moment, due to the sheer number of the sites that need to be documented, and the very fast of undesirable changes in the sites and their buffer zones.

In addition to the above-mentioned qualities, UAVs are also very easy to use and do not require much professional ability (Manajitprasert et al., 2019). This makes UAVs an optimal solution to problems related to heritage documentation. The use of UAVs in the study area could encourage collaborative campaigns between researchers, international organizations, and local governments to document sites more efficiently.

The procedure used in this case study could be very useful for documenting the medium historic area with resolution more than what the satellite imagery can provide. Use of UAV is also an opportunity to develop 3D models for similar historic areas for documentation purpose and integration into the general master plans of the cities.

The point cloud generated by UAV represents as a key to produce more details about the Qishla building, since it could be exported into BIM (Building Information Modeling) in order to produce a BIM model that helps in fusion of data, and produce drawings of the structure such as elevations, plans and sections (Karachaliou et al., 2019; Themistocleous, 2019), that needs further research work. In addition, this information could also be integrated with future information could be collected by laser scan data to have a complete documentation (Korumaz et al., 2014) that needs further investigation.

ACKNOWLEDGMENT:

The author acknowledges the support provided from Department of Surveying at College of Engineering, University of Duhok through using department UAV to conduct this study. The author also acknowledges the role of department staff especially Mr. Lahon Al-Jaff.

REFERENCES

Al-Ruzouq, R. (2012). Photogrammetry for Archaeological Documentation and Cultural Heritage Conservation. In Daniel Carneiro da Silva, Special Applications of Photogrammetry (pp. 97-110). IntechOpen, DOI: 10.5772/35314.

Alsadik, B. (2020). Crowdsource Drone Imagery – A Powerful Source for the 3D Documentation of Cultural Heritage at Risk. International Journal of Architectural Heritage. DOI: 10.1080/15583058.2020.1853851

Al-Jafi, Q. Sh. (2021). Pira Dalal Bridge: Connection between past and present of Zakho City. Available from Xeber website: https://xeber24.org/archives/325408.

Bruno, N., and Roncella R. (2018). A restoration oriented HBIM system for cultural heritage documentation: the case study of Parma Cathedral. In the International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Proceedings of ISPRS TC II Mid-term Symposium “Towards Photogrammetry 2020” in Turkey. Volume XLII-2. Riva del Garda, Italy 4–7 June 2018.

Duhok General Directorate of Antiquities. (2020). Information on Laser Scan and UAV Usage in Duhok and Kurdistan Region. Duhok General Directorate of Antiquities. Duhok Governorate. Kurdistan Region of Iraq.

Duhok Directorate of Constructive Planning. (2021). Archive of Masterplans of Cities in Duhok Governorate From 2013 to 2020. Duhok Directorate of Constructive Planning. Duhok Governorate. Kurdistan Region of Iraq.

Girelli, V.A., Tini M.A., and Zanutta A. (2005). Traditional and unconventional photogrammetric techniques for metrical documentation of cultural heritage: the example of the “Rolandino dei Passaggieri” Tomb (st. Domenico Square) survey in Bologna. In CIPA 2005 XX International Symposium, International Cooperation to Save the World's Cultural Heritage in Italy (pp. 310 – 315). Torino, Sergio Dequal, 26 September – 01 October.

Ismael, Sh. (2015). Promoting Integrated Heritage Conservation and Management in Iraqi Kurdistan Region, Applicability of Values-Based Approach; the Case Study of a Akre and Amedy city in Duhok Province.

International Council on Monuments and Sites (2014). Heritage at Risk World Report 2011–2013 on monuments and sites in danger). 2014. Heritage at Risk. Berlin: Other. [Online]. https://www.icomos.org/images/DOCUMENTS/Publications/HR2011-13final.pdf.

Kilby, T., and Kilby, B. (2018). A Different View: Using Drones to Document Historic Places. Forum Journal. 32(1), 13-21. https://www.muse.jhu.edu/article/701678.

Korumaz, A. G., Korumaz, M., Tucci, G., Bonora, V., Niemeier, W. and Riedel, B. (2014). UAV Systems for Documentation of Cultural Heritage. Proceedings of ICONARCH I-International Congress of Architecture-Innovative Approaches in Architecture and Planning in Konya, Turkey (pp:419-430). 15 – 17 November, 2012. ISBN:978-975-448-206-5.

Khorsheed Mohammed Rasheed and Chiad Abdulsetar Abdulkarim, (2017). Zakho: a town of tolerance and coexistence in ariel Sabar’s my father’s paradise. Humanities Journal of University of Zakho (HJUOZ) Vol. 5, No. 2, pp. 496– 501.

Karachaliou, E., Georgiou, E., Psaltis, D., and Stylianidis, E. (2019). UAV for mapping historic buildings: from 3D modelling to BIM, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-2/W9, 397–402, https://doi.org/10.5194/isprs-archives-XLII-2-W9-397-2019.

Murtiyoso, A., and Grussenmeyer, P. (2017). Documentation of heritage buildings using close-range UAV images: dense matching issues, comparison and case studies. The Photogrammetric Record, 32 (159), 206-229.

Ministry of Culture and Information of the Republic of Iraq, Iraq Directorate General of Antiquities. (1970). Atlas of the Archaeological Sites in Iraq. Baghdad: al-Jumhuriya Press.

Manajitprasert, S., Tripathi, N. K., & Arunplod, S. (2019). Three-Dimensional (3D) Modeling of Cultural Heritage Site Using UAV Imagery: A Case Study of the Pagodas in Wat Maha That, Thailand. Applied Sciences, 9(18), 3640. http://dx.doi.org/10.3390/app9183640

O’Connor, C. (1993). Roman Bridges, Cambridge University Press, ISBN 0-521-39326-4

Sanz-Ablanedo, E., Chandler, J., Rodríguez-Pérez, J., & Ordóñez, C. (2018). Accuracy of Unmanned Aerial Vehicle (UAV) and SfM Photogrammetry Survey as a Function of the Number and Location of Ground Control Points Used. Remote Sensing, 10(10), 1606. MDPI AG. Retrieved from http://dx.doi.org/10.3390/rs10101606

Themistocleous, K. (2019). The Use of UAVs for Cultural Heritage and Archaeology. In Hadjimitsis, D., Themistocleous, K., Cuca, B., Agapiou, A., Lysandrou, V., Lasaponara, R., Masini, N., Schreier, G. (Eds.). Remote Sensing for Archaeology and Cultural Landscapes, Best Practices and Perspectives Across Europe and the Middle East (pp.241-269). Part of SPRINGER NATURE.

Themistocleous, K., Agapiou, A., King, H.M., King, N. & Hadjimitsis, D.G. (2014). More Than a Flight: The Extensive Contributions of UAV Flights to Archaeological Research - The Case Study of Curium Site in Cyprus. Proceedings of the Progress in Cultural Heritage: Documentation, Preservation, and Protection (pp.396-409). 5th International Conference, EuroMed 2014, Limassol, Cyprus. Springer LNCS 8740, EuroMed2014 Conference.

University of Zakho. (2018). Zakho City. University of Zakho Gallery and Activities. Available from https://uoz.edu.krd/zkc.php.

Wang, S., Ahmed, Z., Hashmi, M. Z., and Pengyu, W. (2019). Cliff face rock slope stability analysis based on unmanned arial vehicle (UAV) photogrammetry. Geomechanics and Geophysics for Geo-Energy and Geo-Resources. 5. 10.1007/s40948-019-00107-2.

Yastikli, N. (2007). Documentation of cultural heritage using digital photogrammetry and laser scanning. Journal of Cultural Heritage, 8 (4), 423-427.

Zakho Directorate of Antiquities. (2021). Archive of Qishla Building in Zakho District. Zakho Directorate of Antiquities. Duhok Governorate. Kurdistan Region of Iraq.