MODELING OF THE STRUCTURES WITHIN THE ANCIENT CITY OF KILISTRA (GÖKYURT) USING THE TERRESTRIAL LASER SCANNIG AND UNMANNED AERIAL VEHICLE TECHNIQUES

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ABSTRACT

The present study aims to carry out 3D modeling works for the structures located in the Ancient City of Kilistra (Gökyurt), which exhibits features similar to Cappadocia and Ihlara in terms of its natural rock formation and architecture. The frequent use of photogrammetric techniques in works carried out towards the preservation, protection and documentation of hereditary artifacts, historical structures and geological formations with historical and cultural value is very advantageous in terms of the accuracy, cost and speed of the work carried out as well as numerical documentation and modeling. Terrestrial Laser Scanning and Unmanned Aerial Vehicle (UAV) techniques are among the significant methods in terms of the protection and documentation of historical and cultural heritage.Within the scope of the present study, interior space measurements of the Başpınar Cistern, Ceramic Workshop and Church of the Cross located in the Ancient City of Kilistra, an important settlement in historical terms, were performed using a terrestrial laser scanner while exterior space measurements were performed using an unmanned aerial vehicle. Additionally, 2D drawings unique to the artifacts were created and geometric information such as area, volume and circumference were extracted. Within the framework of the study, 3D models were produced using data obtained from different platforms.

1. INTRODUCTION

Ancient Cities have become places of attraction for tourists who are curious about the traces of different past civilizations, and touristic ancient cities also contribute to cultural tourism and national economy with their increasing number of visitors. The protection and documentation of landmarks, which form a bridge between the past and present of humanity and have cultural and historical value, have become easier, quicker, economical, and more attractive with technological methods that have been developed in recent years (Brumana et al., 2014; Fawzy 2019). It is notable that photogrammetric techniques are commonly used in works carried out towards the preservation, protection and documentation of hereditary artifacts, historical structures and geological formations with historical and cultural value. The digital photogrammetry technique, which is regarded as being among advanced technological methods, has been commonly used in studies conducted towards the protection and documentation of historical and cultural heritage in recent years (Barber et al., 2002; Ingensand et al., 2003; Staiger 2003; Fröhlich and Mettenleiter 2004; Sanna and Pralio 2005; Yılmaz and Yakar 2006; Gümüş and Erkaya 2007; Everaerts 2008; Karabörk et al., 2017). One of the areas where interdisciplinary cooperation is most required is architectural restoration work, which aims to preserve cultural heritage and pass structures down to future generations in their most original condition and functions (Balis et al., 2004; Abmayr et al., 2005; Remondino et al., 2005; Yastikli 2007; Al-Kheder et al., 2009; Remondino 2011; Şenkal et al., 2013). It is observed that terrestrial laser scanning and UAV platforms are utilized in the documentation of historical and cultural areas, as well as the protection and documentation of protected archaeological areas (Lerma et al., 2010; Remondino et al., 2011; Barsantia et al., 2013; Núñez et al., 2013; Stal et al., 2014; Hatzopoulos et al., 2017; Jo and Hong 2019; Ulvi 2021; Kaimaris 2022; Panagiotidis and Zacharias 2022). Furthermore, photogrammetric techniques benefit a variety of fields by exporting three-dimensional models of works to other Computer Aided Design (CAD) software and to various 3D data formats with texture mapping, such as Virtual Reality Modeling Language (VRML) (Psarros et al., 2022). In comparison to standard measuring approaches, terrestrial laser scanning is a measurement technique that can gather 3D point information at a very high speed. The terrestrial laser scanning approach, in particular, is useful for 3D modeling in indoor measurements because it allows for quick data capture and interpretation. The technique is important now and in the future in terms of modeling interior spaces and transferring these models to GIS after merging them with objects and databases, conveying this transferred model to a large number of users over the internet, displaying the interiors of functional buildings in a visible manner within a virtual world, and allowing users to virtually walk around these spaces. Therefore, it is possible to conveniently obtain precise information regarding the structure whose interior is modeled, as well as to reach a desired point in the interior (Budroni and Böhm 2010; Avdan et al., 2013). 3D models of objects are generated by recording point clouds, merging them using various methods and deleting excess point data.

Unmanned aerial vehicles, on the other hand, are special-purpose vehicles that can take off and land in any location and have remote control, semi-automatic, or fully automatic flight capabilities (Antoine et al., 2020). The most significant advantage of UAVs is that they may be employed in potentially dangerous situations and inaccessible places without endangering human life, at low altitudes and in scenarios where the flight profile is near to the object and manned flight systems cannot fly (Howard et al., 2018).

The structures of the ancient city of Kilistra located within the borders of Gökyurt district in Konya, which is one of the ancient cities that has not been fully opened to cultural tourism but plays a significant role in faith tourism for international visitors in particular, has been investigated in the present study. Many artifacts have survived to the present day at the ancient city of Kilistra, which serves as an open-air museum. Chapels, churches, monasteries, cisterns, wineries, workshops, and fountains are examples of these works. These structures that make up ancient cities and archaeological remains are documents. However, the physical properties of the structures and the risky situations that make it difficult to measure can limit obtaining results with the desired accuracy and precision. Therefore, appropriate measurement and documentation methods should be preferred to obtain accurate volume, area, and dimension information regarding the building. Within the scope of the study, it has been aimed to create 3D models of the Church of Cross, Ceramic Workshop, and Başpınar Cistern, which are among the works of different sizes and features in the ancient city of Kilistra. It is very difficult to document accurately and quickly with traditional measuring methods, especially since the Ceramic Workshop and a part of the Başpınar Cistern are underground and consist of workshops and carriers of different sizes. Therefore, the interior measurements of these structures were carried out by terrestrial laser scanning method. The exterior measurements of the Ceramic Workshop and Cross Church, which are dangerous to reach and measure

with the terrestrial laser scanning method were carried out with an unmanned aerial vehicle system. In addition, by combining TLS and UAV data, it is aimed to complete the missing data that cannot be obtained with a single measurement method and to enrich the 3D model outputs. The data obtained with different measurement methods were evaluated with different software, and the resulting products were compared, three-dimensional models and metric information were produced.

2. MATERIALS AND METHODS

2.1. The study area

Ancient cities carry undeniable importance for cultural tourism, a sub-branch of tourism. Ancient cities that housed numerous civilizations in the past and occasionally served as capitals are among the key destinations of local and international tourists who participate in cultural tours in our country. Tourists interested in the vestiges of various civilizations are flocking to ancient cities, which are becoming tourist hotspots. The history of the Ancient City of Kilistra (Gökyurt), which serves as an open-air museum, extends back to the Bronze Age, with settled life beginning in the Hellenistic and Roman periods (2nd century BC – 3rd century BC). The location lies along the historic "Royal Road," which links Anatolian cities with Antakya. The Persian king Darius the Great created this ancient road in the 5th century BC to communicate more effectively throughout his empire. Moreover, on Saint Paul's first missionary voyage, he visited Konya and Lystra (Hatunsaray), and Christianity began to spread in the region. Kilistra occupies a significant position in terms of faith tourism in this regard (Bahtiyar and Dişli, 2020).

Figure 1. Study Area-Kilistra Ancient City

Kilistra is 45 kilometers southwest of Konya and contains natural rock formations and architecture that are similar to those of Cappadocia and Ihlara. The region was formed at five different locations, each running along to natural rock formations. A rock-cut settlement style was elected to keep the city's construction a secret. The rooms in the rock dwellings were extended, and a system of passageways connected them to an underground city. When viewed from afar, the interiors of the houses, which resemble natural rocks, are carved into large spaces, with concealed crevices and chimney openings for lighting and ventilation. The settlement also contains places of worship such as chapels, churches, and monasteries, as well as social areas such as residences, cisterns, wineries, workshops, fountains, and tombs, and defensive and security structures such as watchtowers, garrisons, police stations, and shelters. Kilistra and its surroundings are made up of monolithic volcanic tuff that dates back to the Upper Miocene epoch. The andesite pebbly surface structure of the region resembles that of the Cappadocia, Ihlara, and Taşkale (Karaman) formations. The settlement, currently known as Gökyurt, is situated on a plateau with steep slopes and soft lava formations. (Aydın 2008; Tapur 2009; Mimiroğlu 2014; Bozkurt 2016).

Important structures in Kilistra

Figure 2A. Church of the Cross

The Church of the Cross is located in the northern section of the settlement, in the Konacak region (Figure 2A). A chapel, ambulatory, naos, and burial chamber make up this church, which was cut out of a massive bedrock. On the west side of the church, the entrance is in the shape of a rectangle with a tunnel vault. The church's naos is reached by a rectangular hole near the entryway. A rectangular aperture also leads to the church's burial chamber in the northwest corner. The church involves three different decorations. These can be listed as: reliefs carved into the bedrock, frescoes, and geometric embellishments made of red graft beneath the paintings (Mimiroğlu 2014).

Figure 2B. Ceramic Workshop

The ceramic workshop is made up of buildings that are positioned next to each other in a neighborhood in Kilistra's northwest region (Figure 2B). Most of the workshops, which had a common kiln and a large pool, are now under the ground, according to the information obtained through the ruins. Pools and alcoves of various sizes are located throughout the workshops, which are connected by small apertures. The ceramic workshop complex is made up of three main workshops, a kiln, and a pool carved out of a bedrock on the same ground level at the north side. The upper half of the entrance was covered with a wooden roof during restoration work in the region in 2003 (Mimiroğlu 2014)

Figure 2C. Başpınar Cistern

The Başpınar Cistern, located northwest of Kilistra, is the region's largest cistern (Figure 2C). The cistern, which has an irregular rectangular form, was carved out of bedrock beneath ground level. There is an entrance and a main section to the cistern. The canal that runs in front of it was dug out of bedrock. Another small canal was added to it, and the two were connected by two apertures at the cistern's entrance. The cistern's entrance is a rectangular opening that extends 2.40 meters above the channel level. The main section of the cistern has an irregular rectangular form and is 1.90m lower than the entrance, requiring a five-step descent. In the main section, containers of various sizes are carved into the bedrock and joined by arches. At the base of the eastern part of the main area, there is a pit. The cistern derives water through a hole in this pit (Mimiroğlu 2014)**.**

2.2. Data Acquisition

2.2.1 Terrestrial Laser Scanning

To collect data regarding the key structures within the Ancient City of Kilistra, two different measurement technologies were used in the present study. The photogrammetric data for the exterior spaces was gathered by an unmanned aerial vehicle, while the data for the internal spaces of the structures was obtained using a terrestrial laser scanning system. Laser scanning is a method in which a surface is sampled or scanned using the LiDAR (Light Detection and Ranging) technology. Through the optical source conceptualized as laser beams, the distance between the laser scanning device and the object can be determined. In the laser scanning technology, time-of-flight, phase-

based scanning and triangulation methods are used (Lõhmus et al., 2018; Wang 2020). The time-of-flight distance measurement method measures the round trip time of the laser beam reflected from the object surface while the phase-based scanning method, which operates in accordance with amplitude modulation, compares multiple laser signals to measure phase difference (Shan and Toth, 2018). The FaroFocus 3D X 330 operating with the phase-based distance measurement approach was employed in the present study. A high-speed three-dimensional laser scanner, the FaroFocus 3D X 330 is used for precise surveying and documentation. It produces highly detailed three-dimensional photographs of complex surroundings and geometries in just a few minutes using laser technology. Focus 3D operates on the premise of sending an infrared laser beam to the center of a revolving mirror (Monsalve et al.,2019). The laser beam in the scanned environment is deflected by this instrument's revolving mirror (Pajalić et al., 2021). Light emitted by objects in the immediate vicinity is reflected back to the scanner. The x, y, and z coordinates of each point can be computed by monitoring the mirror rotation and the horizontal rotation of the instrument. A polar coordinate (δ, α, β) is formed by distance, vertical angle, and horizontal angle. The tool then transforms these polar coordinates to Cartesian coordinates (x, y, z) (Lichti et al., 2019). Focus 3D also measures the intensity of the received laser beam to determine the reflectivity of the captured surfaces (Tan et al.,2018). Interior measurements of the Church of the Cross, the Ceramic Workshop, and the Başpınar Cistern, all of which are among the artifacts located in the ancient city of Kilistra, were taken in 26 different sessions, 10 of which were conducted at the Başpınar Cistern, 11 at the Ceramic Workshop, and 5 at the Church of the Cross, using a Faro Focus3D X330 laser scanner. The locations and number of areas to be scanned, the station points to set up the instrument, and the scan's spatial resolution were all specified prior to scanning. Each scanning operation was designed to cover at least four target plates created in common overlap areas with dimensions of 20 cm * 15 cm. The target plates are 20 cm * 15 cm in size and are made in black and white.
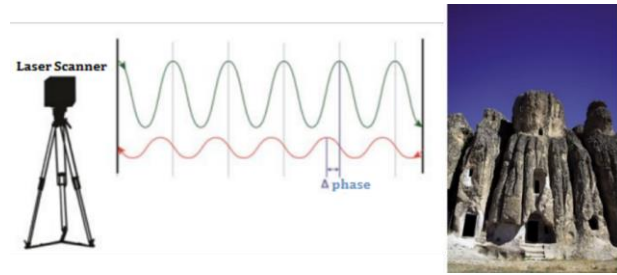

Figure 3. Terrestrial Laser Scanning

2.3. Data processing and results

The Faro Scene and JRC 3D Reconstructor softwares were used for the 3D modelling of the data. The process step was initiated for the processing and combination of raw data obtained from various sessions. In this step, the scanned point clouds for each session were obtained in this step by using parameters such as scanning coloring, reflectance threshold, distance filter, target plate determination, and so on. Automatic and manual registration was used to combine the point clouds. It is necessary to combine point clouds obtained from different stations in a common coordinate system. These coordinates obtained are tool-based, and the reference coordinate system must be determined. If the reference system to be determined is a geodesic coordinate system, it is necessary to coordinate the target marks established in the planning process prior to scanning. Table 1 shows the statistical scanning values regarding the registration result from the FaroScene software.

Table 1 Results of the registration system performed in the Faro Scene software

Scanning Statistic	Mean Point error	Maximum Point error	Minimum overlap
Başpınar Cistesn	1.1 mm	1.6 mm	% 35.1
Ceramic Workshop	1.0 mm	1.7 mm	% 32.4
Church of the Cross	**0.9 mm**	**1.0 mm**	**% 58.6**

Following the registration phase, an abstract point cloud was obtained by removing the unnecessary points within the resulting point cloud and homogenizing the point density. The visuals regarding the 3D modelling process steps of the Başpınar Cistern, Church of the Cross and Ceramic Workshop are presented below (Figure4).
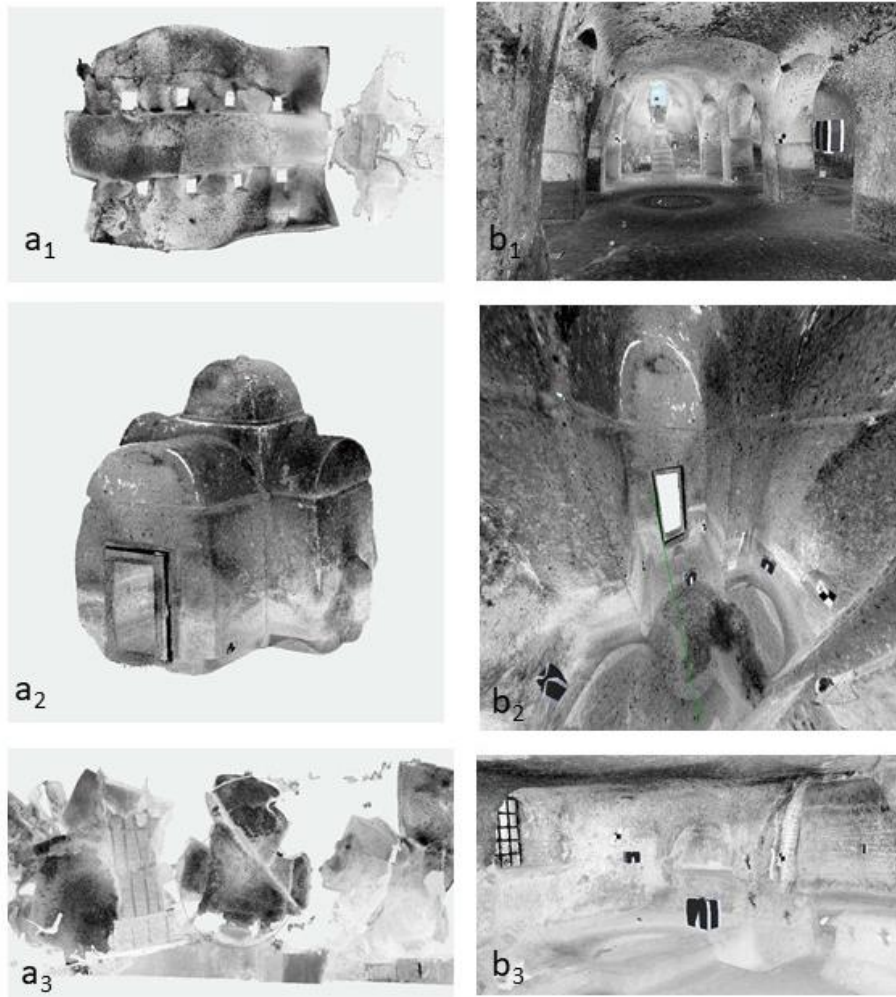
Figure 4. Data processing a1) Exterior borders of the Başpınar Cistern point cloud visual b1) Interior space of the Başpınar Cistern point cloud visual, a2) Exterior borders of the Church of the Cross point cloud visual b2) Interior space of the Church of the Cross point cloud visual, a3) Exterior borders of the Ceramic Workshop point cloud visual b3) Interior space of the Ceramic Workshop point cloud visual

The interior and exterior scans of the Church of the Cross were also analyzed utilizing automatic and manual registration methods in the present study. Exterior scans make up one of the scans, while interior scans make up the other. The program does not automatically connect the exterior and interior spaces in automatic registration. As a result, the registration operation's results are inaccurate. Manual registration is time-consuming and exhausting in and of itself, but it is more effective than automatic registration in connecting exterior and interior spaces. To compare the different registration results, the interior scans that were registered automatically were manually registered with the exterior scans, and a 3D model was created. By raising the overlap ratio, this hybrid technique decreases point errors while also providing more accurate findings. The results of automatic, manual, and automatic + manual registration using the FaroScene software are shown in Table 2.

Table 2. Comparison of the Faro Scene automatic and manual registration methods

| Scanning Statistic	Automatic Registration	Manual Registration	Automatic + Manual
Maximum point error	1.2 mm	1.1 mm	1.0 mm
Mean point error	1.1 mm	1.0 mm	0.9 mm
Minimum overlap	%25.1	%29.8	% 58.6

JRC 3D Reconstructor is another program that examines the raw scan data obtained with the Faro Focus terrestrial laser scanner. Data preprocessing and fine registration steps produced a point cloud for each laser scanning session. In the Single Point Cloud stage, these point clouds were blended into a single point cloud. The average ICP error and post-registration Average Registration Error of Corresponding Points of the Başpınar Cistern, Church of the Cross,

and Ceramic Workshop were determined (Table3). In the following stage, a Mesh was generated from point clouds. Options such as the number of Mesh triangles, point cloud smoothing filters, ways to fill missing points, and Mesh colors are shaped according to each project in 3D Mesh development. Figure 5 shows the visuals related to the point cloud of the Başpınar Cistern, Church of the Cross, and Ceramic Workshop generated using the JRC software and the 3D Mesh model. According to the 3D model results obtained using different soft-ware, the JRC 3D Reconstructor software produced more point clouds, mesh triangles

and mesh vertices compared to the Faro Scene software (Table 4).

Table 3. Comparison of the Faro Scene automatic and manual registration methods

Scanning Statistic	Average ICP Error	Average Registration Error of Corresponding Points
Başpınar Cistesn	0.963 mm.	1.135 mm.
Ceramic Workshop	0.986 mm.	1.318 mm.
Church of the Cross	0.944 mm.	0.951 mm.
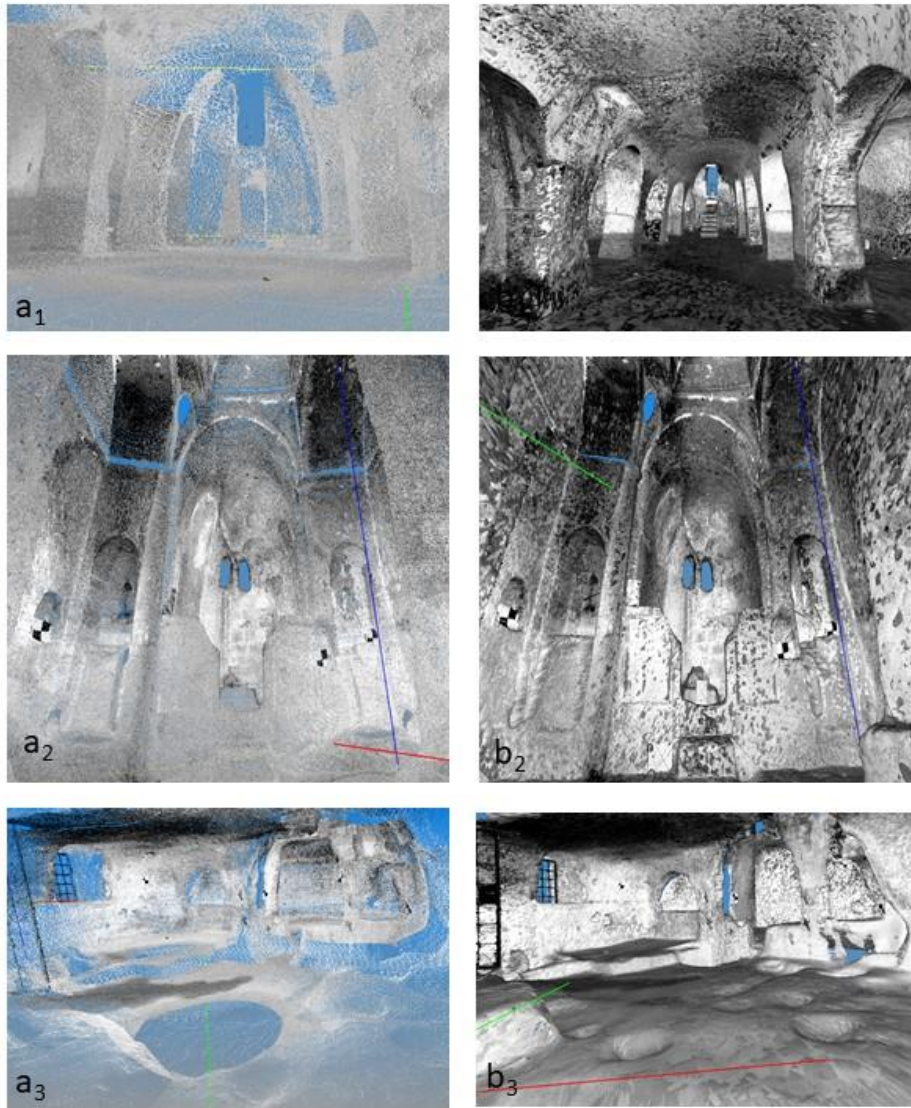
Figure 5. Mesh process a1) Başpınar Cistern point cloud b1) Başpınar Cistern 3D Mesh visual, a2) Church of the Cross point cloud b2) Church of the Cross 3D Mesh visual, a3) Ceramic Workshop point cloud b3) Ceramic Workshop 3D Mesh visual

Table 4. Comparison of outputs in the Faro Scene and JRC softwares

Scanning Statistic	Software	Number of Point Clouds	Number of Mesh Triangles	Number of Mesh Vertices
Başpınar Cistern	Scene	228 049 381	2 761 938	1 382 818
	JRC	277 326 609	5 973 414	3 371 766
Ceramic Workshop	Scene	221 830 522	2 038 995	1 023 923
	JRC	256 285 289	6 417 499	3 219 436
Church of the Cross	Scene	82 805 025	1 894 739	948 655
	JRC	109 540 414	7 001 466	3 500 791

2.4. *Assessment of three-dimensional models derived from TLS data*

2.4.1 Two-dimensional drawing and area calculation

The DrawToAutoCAD tool of the Faro Scene software was used to generate 2D drawings of the 3D models. Because the DrawToAutoCAD tool included in the Faro Scene works simultaneously with the AutoCAD software, this application is highly useful for 2D drawings. The drawing was produced by connecting to the AutoCAD software through a cross section of the 3D models (Figure 6). Based on the 2D models obtained, the areas and circumferences of the structures were calculated using the AutoCAD software. Table 5 shows the area and circumference calculation results.

Table 5. Area and Circumference calculations of the Cistern, Church and Workshop

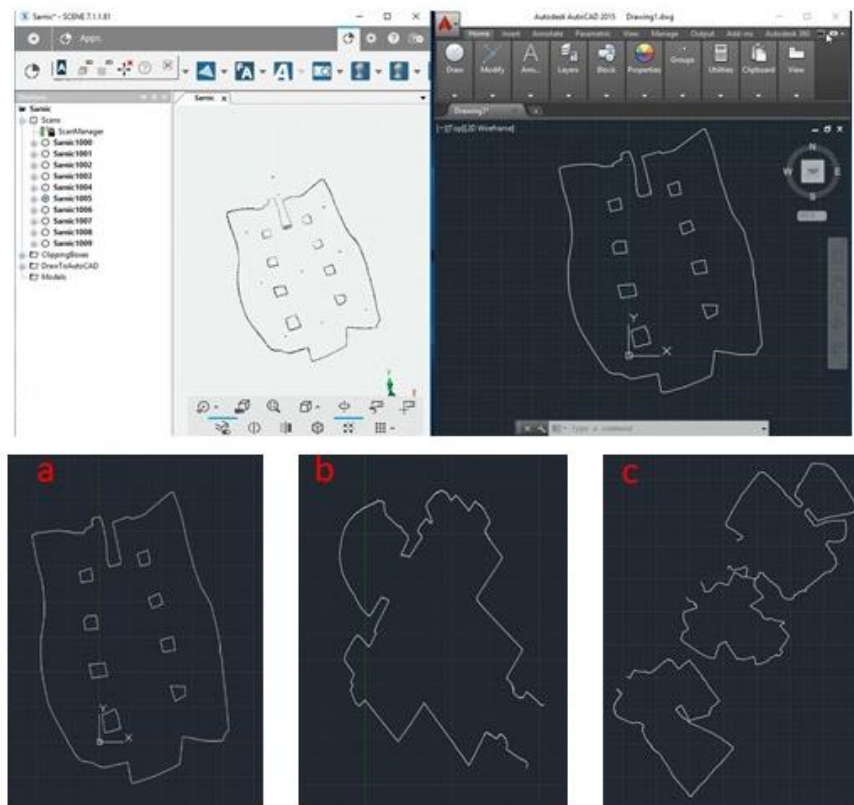| Scanning Statistic	Area	Circumference
Başpınar Cistern	230.209 m²	63.67 m.
Church of the Cross	47.508 m²	37.44 m.
Ceramic Workshop 1	58.45 m²	41.51 m.
Ceramic Workshop 2	33.90 m²	29.41 m.
Ceramic Workshop 3	47.508 m²	36.17 m.
Ceramic Workshop total	139.858 m²	107.09 m.

Figure 6. CAD drawings of the 3D models a) Başpınar Cistern b) Church of the Cross c) Ceramic Workshop

2.4.2 Volume calculation

The volume of non-regular geometrically shaped objects can be determined using point cloud data. 3D models make it simple to gather mathematical information about an object. The software was used to calculate the water storage capacity of the Church's dome and the Başpınar Cistern. The volume of the dome was calculated using the 3DReashaper software, and the water storage capacity was calculated

using the JRC 3D Reconstructor software. After transferring the dome's 3D model to the 3DReashaper software, a 3D mesh was generated, and the volume of the dome was determined to be 1.993 m³ (Figure 7). A horizontal plane was generated in the JRC 3D Reconstructor software to compute the water storage capacity of the Başpınar Cistern, and the volume was calculated using a 3D point cloud. The water storage capacity of Başpınar Cistern was calculated as 163.074 m³ (Figure 8).
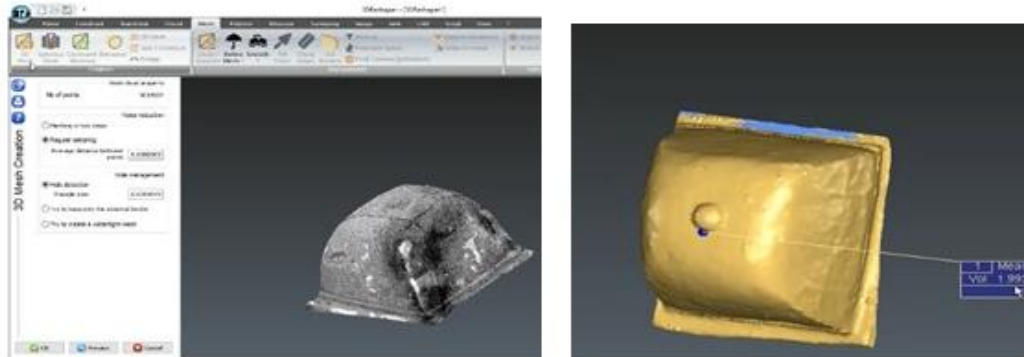
Figure 7. Generation of a 3D mesh for the Church of the Cross in the 3DReashaper software and volume calculation
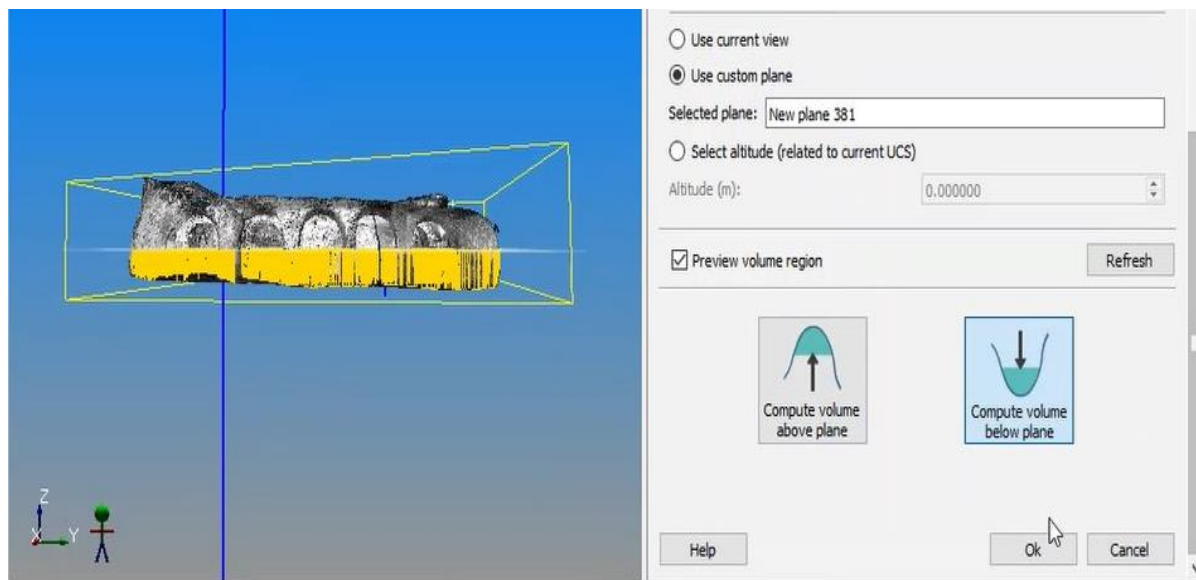
Figure 8. Calculation of the water capacity of the Başpınar Cistern using the JRC 3D Reconstructor software

2.5. *Modeling with Unmanned Aerial Vehicle*

The 3D model of the ceramic workshop and the Church of the Cross was created using the DJI Phantom 3 Unmanned Aerial Vehicle. This vehicle, which features a 12 MP resolution HD camera and a dual frequency GNNS receiver, has a flight time of up to 25 minutes. The study area's borders were determined prior to the flight, and ground control points measuring 50 * 50 cm were produced and placed in the study area in a suitable distribution so that they could see each other. The Ceramic Workshop's ground control points were established and measured, as were the Church of the Cross's ground control points. In the local system, the coordinates of the ground control points employed in the application were evaluated. The flying procedure was initiated, and the roofs of the workshop and the church were photographed, as per the flight plan produced during the data gathering phase using the UAV. For the images of the lateral facade, a second flight was done. The 3D models of the Workshop and the Church were created using the Agisoft and Pix4D software.

2.5.1 3D modelling with the Pix4D software

To begin, the data collected by the Unmanned Aerial Vehicle was processed using the Pix4D software. The images from the field work were carefully chosen and imported into the software. The initial processing was started after the aerial photographs were transferred to the Pix4D program. The camera position of the photos was determined at this point, and the software generated the Tie Points. A 3D model of the roofs and side facades of the Ceramic Workshop and the Church was created using the Pix4D software (Figure 9).
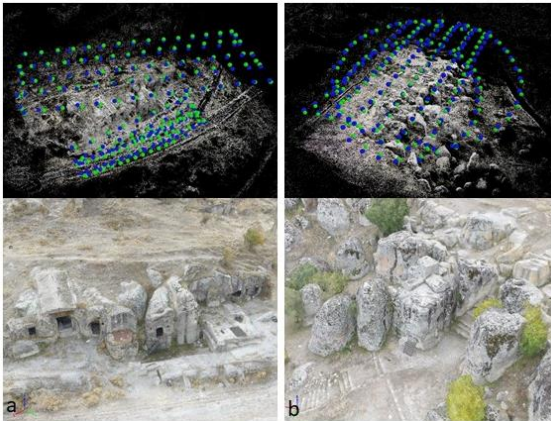
Figure 9. Camera positions and 3D model in the Pix4D software a) Ceramic Workshop b) Church of the Cross
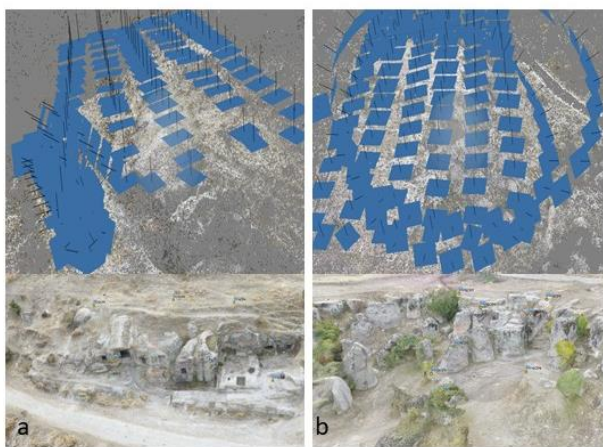

Figure 10. Camera positions and 3D model in the Agisoft software a) Ceramic Workshop b) Church of the Cross

2.5.2 3D modeling with the Agisoft software

Agisoft is the other program used to model UAV data. The photographs taken in the field were chosen and imported into the software. In Agisoft, the initial step is to align aerial photos. The software then discovers the intersecting images' matching points, estimates the camera position of each photo, and generates a sparse point cloud model. The creation of a Dense Point Cloud is the next phase. Agisoft calculates the depth information for each camera, condensing it into a single dense point cloud, based on the projected camera placements. Mesh and Texture Models can be constructed after the dense point cloud has been established. The final 3D model, the Tiled Model, can be constructed when the Mesh Model is completed (Figure 10). In addition, the impact of using and not using ground control points in 3D modeling studies with UAV data on modeling results was explored as part of the present study. The results of modeling the Ceramic Workshop with a ground control point against without a ground control point were compared (Table 6). The GCP approach produced substantially higher-quality findings. The

model results obtained using GCP, for example, are more favorable in terms of both the number of connection points and the tiled model resolution, as well as the Digital Elevation Model (DEM) and Orthomosaic resolution.

Table 6. Modeling results of the Ceramic Workshop with and without GCPs

3D Modeling Results	Modeling with GCPs	Modeling without GCPs
Tie Points	258 073	199 117
Tiled model resolution	0.318 mm/pix	8.95 mm/pix
Resolution of the DEM	1.2725 mm/pix	35.811 mm/pix
Size of the DEM	3862*3849 pix	4469*4376 pix
Orthomosaic resolution	0.318 mm/pix	8.95 mm/pix
Orthomosaic size (in pixels)	14980*15072	17875*17495

3. DISCUSSION

The Başpınar Cistern, Church of the Cross, and the Ceramic Workshop were first studied using terrestrial laser scanning data and modeling. Manual and automatic registration were used to combine point cloud data from separate sessions, and the outcomes were compared. Exterior and interior sessions could not be linked during automatic registration with the Faro Scene program. The results of manual registration were found to be more successful than automatic registration, but the process took a substantial amount of time. Using both the automatic and manual techniques to register data is another option. Only the interior scans are automatically registered in this approach, and they are manually linked with exterior scans. As a consequence, automatic registration alone had a precision of 1.2 mm, whereas manual registration alone had a precision of 1.1 mm, and auto+manual registration had a precision of 1.0 mm. Point errors are decreased and the overlap rate is raised in the method that combines automatic and manual registration. JRC 3D Reconstructor is another program that combines the same scan data. This software uses the ICP method to register point cloud data. According to the findings, the Başpınar Cistern was registered with a precision of 0.963 mm, while the Ceramic Workshop had a value of 0.986 mm and the Church of the Cross had a value of 0.944 mm. When comparing the two softwares, it is clear that the JRC 3D Reconstructor software produced more accurate results than the Faro Scene software. Furthermore, the JRC 3D Reconstructor software produced superior point clouds, mesh triangles, and mesh vertices than the Faro Scene software (Table 6). Information such as area and length may be easily accessed by working simultaneously with the Faro Scene program's AutoCAD soft-

ware and producing 2D drawings via the DrawToAutoCAD module. A horizontal plane was generated in the JRC 3D Reconstructor software to determine the water storage capacity of the Başpınar Cistern, and the volume of the cistern was computed using a 3D point cloud. The Başpınar Cistern's water storage capacity was determined to be 163.074 m³, while the cistern's dome volume was calculated to be 1.993 m³.The Faro Scene program processes data more conveniently and quickly than the JRC software when it comes to terrestrial laser scanning data evaluation software. The strengths of the JRC 3D Reconstructor software over Faro Scene are that it has many more parameters, generates an unlimited amount of point cloud and mesh triangles, allows a wide range of point cloud and mesh generating and editing commands, and supports a wide range of geometric applications.

The 3D models created from aerial pictures taken using the unmanned aerial vehicle platform are another method explored in the scope of the present study. Side facade and roof photos for the Ceramic Workshop and the Church were collected with different flights in accordance with the flight plans specified. Photographs were shot with an 80 percent overlap parallel to the landscape to model the roof of the ceramic factory, and 30 percent inclined to model the side facades of the ceramic workshop. The Church's roof flights were 80 percent overlapped, and the side facade flights were created in a circular pattern from 15m to 20m in height. 329 aerial images were taken in all, with 165 for the Ceramic Workshop and 164 for the Church of the Cross. In 3D modeling experiments involving unmanned aerial vehicle data, the Agisoft and Pix4D software were employed. Before the flight, ground control points were constructed on the ground and their coordinates were measured locally. 3D models were constructed over the dense point cloud after the aerial images and GCPs were imported to the software. Despite the fact that the Pix4D software is simpler and faster to use than the Agisoft software, the Agisoft software delivers superior outcomes by employing more parameters during the 3D model development process. While the Pix4D software offers automatic and restricted-resolution solutions for DEM and orthomosaic production, the Agisoft software is more beneficial with DEM and orthomosaic sizes, producing data in a number of resolutions, a variety of output extension types, and other possibilities. Limiting Pix4D's maximum mesh triangle number to 20 million and DEM resolution to 1 cm/pixel causes distortion in DEM and orthomosaic

photographs. Furthermore, the modeling of the Ceramic Workshop in the Agisoft software was performed with and without GCPs, and the precision acquired as a result of the balancing performed using GCP points has been demonstrated to be quite favorable, according to the data obtained.

4. CONCLUSION

With the advancement of technology in recent years, measurement and assessment procedures in studies undertaken for protection and documentation have changed, and extensive survey studies on 3D models have become easier to do with the use of advanced technological systems. In today's studies for the protection and documentation of historical artifacts, sites, monuments, and natural formations, the employment of terrestrial laser scanners and unmanned aerial vehicle platforms, in addition to close-range photogrammetry, stands out. In comparison to traditional measurement methods, these technologies deliver fast, cost-effective, and highly accurate results in 3D modeling experiments. Plans, sections, and views at various scales can be acquired by translating the final products into other data formats, or virtual reality, such as VRLM, can be constructed by overlaying textures on the models.

In the present study, the Başpınar Cistern, Church of the Cross, and Ceramic Workshop, all significant artifacts in the Ancient City of Kilistra located within the borders of the Konya province, which has similar features to the natural rock formations and architecture of Cappadocia and Ihlara, were modeled using terrestrial laser scanning and unmanned aerial vehicle techniques. The capabilities, shortcomings, and superiorities of various software in 3D modeling applications were shown by assessing the same data structure with different software. The outputs acquired using CAD and GIS software were not restricted to only 3D models but included vector and raster data from these 3D models. Furthermore, by moving 3D models to the CAD environment, information such as the cistern's area, size, and water storage capacity, which is difficult to establish using traditional methods, was easily calculated. Merging the data obtained using two or more measurement methods contributes to the completion of missing data (that cannot be obtained with a single measurement method) using other measurement methods, and the enrichment of 3D model outputs. It's particularly useful for 3D modeling of objects that are dangerous or impossible to access, historical artifacts, archaeological structures, and steep, high natural formations.

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