A Survey of Historic Buildings in Sivrihisar Using Advanced Technologies

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***Abstract* – The built heritage is one of the most valuable reminiscences of the human past. It is constantly in danger of being lost or irreversibly altered in the current time due to various impacts of our daily activities. Therefore, there is a continuing need to document still standing historic fabrics and associated structures Afterward, sound decisions are possible to be undertaken and mistakes avoided. Advantage of our time is availability of new technologies which enable precise and fast record generation. This paper aims to give an overview and discuss the application of new technologies in historic buildings survey, in particularly 3d laser scanning, drone recording and 3D modeling using digital photos, which are applied in conservation master studio at Fatih Sultan Mehmet Vakıf University in Istanbul, and its benefits and significance for the advancement of education in the future.**

***Keywords* – conservation studio, built heritage, 3d recording.**

1. Introduction

Built heritage requires special care which usually starts with understanding its values and authenticity. Even though being defined by internationally accepted doctrines and valued as an irreplaceable resource there are many threats present, which range from natural disasters to those of man made (planned or unplanned activities).

DOI: 10.18421/SAR54-09
https://doi.org/10.18421/SAR54-09

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Received: 18 November 2022.
Revised: 17 December 2022.
Accepted: 21 December 2022.
Published: 26 December 2022.

Decision making is the key step in defining future of built heritage and therefore it is of enormous importance to be based on proper documentation. This involves record as well, and for particular heritage asset in subject it may be done on different scale including details. Therefore, today's education in conservation are incorporating training and knowledge in conducting records based on both traditional principles (using regular traditional tools) as well as applying highly sophisticated technologies (using terrestrial laser scanning, digital cameras, drones with photogrammetry software for Structure from motion (SfM).

The documenting heritage assets involve following steps:

- Research (archival research, collecting old photos and documents, maps, literature overview, understanding history of the place and building in subject, and its status in the past, detecting and defining any changes of physical, sociocultural, and economic fabric, and its state, any other useful information provided by relevant sources or institutions, and etc.);
- Site work: engage inventory and survey of the structure and fabric. Here professionals are expected to understand historic fabric or remains, and to be able to prepare sketches and take relevant notes. This step is followed by record.
- Survey and Record: this phase includes photographic documentation of the heritage asset, measuring, and surveying with traditional method and tools (hand survey and theodolite) or with the application of new technology devices (laser scanning or photogrammetry). Uluengin [1] described details of surveying state of conservation by traditional recording methods and he also defined the tools used. This method requires more time and effort. Instead, survey with new technology has advantage of saving time and provides accurate record even for areas with difficulty to approach. There are two possible options, in particularly terrestrial laser scanning or photo based 3D models (SfM). Haddad [2] summarized the difference between the two available options stating that the photo model software helps to extract accurate measurements and to obtain 3D models based on photographs. Second option, terrestrial laser scanners

directly produce a huge number of 3D points which can be processed to form a point cloud model. Several types of laser scanners are available today, depending on subject of the record [3].

Here it is to remark that the two mentioned options are also available to be used in combination since the model produced with a scanner may lack information regarding surfaces and texture which can be obtained in combinative techniques.

Hassani [4] gave detailed overview of pros and cons of all surveying techniques which are in brief categories as image based, non-image based, and combinative techniques, whereas non-image based includes traditional terrestrial survey and laser scanner methods, and image based structured-light and photo laser scanner.

▪ Detailed drawing of the current state of conservation includes detailed analysis for materials, type of damages, details, and etc.

Afterwards, following stages are preparation of reconstitution and proposal for restoration. Various tasks are engaged during documenting historic fabric (structures or sites) among which record provide base according to which all the decisions are to be brought.

This paper will reflect the experience of Fatih Sultan Mehmet Vakıf University in Türkiye, Master Study in Conservation, at Conservation Studio I, conducted during 2019-2020 Academic Year, Fall Semester.

2. Scope of Conservation Studio at FSMVU

The studio is arranged as one semester (14 weeks), in particular, there are 4 hours per week which in total encompasses 56 hours during a semester of studio work under supervision. As a part of studio curriculum and master program in conservation generally, the students are introduced to the importance of documenting built heritage assets, as well as about methods engaged. The studio work also requires additional hours for site work, research, and preparing drawings, which students develop organized in groups, 3-5 students approximately.

Since the typology of build heritage varied in type as well in scale, it is of quite importance to engage students in different levels. Therefore the master studio in FSMVU is arranged as one semester focusing on urban conservation level (urban fabric) while the one taken as case study for this article is focused on the single structures. For the particular fall semester of 2019-2020 as a case study, Sivrihisar, small town in central Anatolia was selected. Historic structures of different scales were given to students who were expected to conduct all phases for proper documentation of the buildings, while this paper will focus only on record with emphasis on the importance of new technology used in this work.

3. Case Study: Survey of Historic Buildings in Sivrihisar

Sivrihisar is currently a small town near Eskisehir in central Anatolia in Turkey (Figure 1). It is located near the King's Road, which was the transportation network of the Phrygian Period [5] 13 km from the small town of Sivrihisar. There was a city named Pessinus located in the Turkish village of Ballıhisar, on the Sakarya river's tributary valley in the high Anatolian plateau at about 950 m above sea level [6].

Figure 1. Eskişehir and its districts [7]

In the 5th century Byzantine period, the Pagan city completely lost its importance with the influence of Christianity. In the 6th century, the Byzantine Emperor Justinianus rebuilt the city, giving the name “Justinianopolis” to the current location of Sivrihisar in order to revive it [8]. In the construction of the Late Antique city, the marbles of the Hittite cities and the city of Pessinus were collected and used [8]. Sivrihisar has become important in terms of economy and military in a short time [5]. The Arab raids against the Byzantines in the time of Caliph Ömer continued until the domination of the Turks in Anatolia. With the battle of Manzikert in 1071, the gates of Anatolia were opened to the Turks. Conquered Sivrihisar was named Karahisar because of its black rocks in this period [5].

Although the exact date of Sivrihisar’s transition to Seljuk rule is not known, Sivrihisar Great Mosque (on the tentative list of UNESCO) was built by Leşker Emir Celaleddin Ali in 1231-1232 [9]. Furthermore, structures such as the Ulu Mosque, Haznedar Masjid, Kılıç Masjid, Hoca Yunus Tomb since the 13th century indicate the beginning of 13th century as terminus ante quem.

After the last period of the Seljuks, Sivrihisar came under the auspices of the Mongols, Karamanoğulları and in 1415, respectively, the Ottomans [5]. Under the Ottoman rule, first Sivrihisar was a small town of Bursa Sanjak, later Hüdavendigar Sanjak, then it became part of Ankara Sanjak (Figure 2), and finally it became a part of Eskişehir in 1915 (see: Türkiye Cumhuriyeti Devlet Arşivleri Başkanlığı, Başbakanlık Osmanlı Arşivi Documents no: DH.HMŞ.2.2._Hicri 14.09.1334 (1915/1916); Y.PRK.KOM. 5.46_Hicri 29.11.1304 (1886/1887); İE.AS.21.1916_Hicri 1089 (1678/1679); A.DVNSMHM.d.8.856_Hicri 10.02.978 (1578/1579) UMVM, nr. (I 23/ I28).

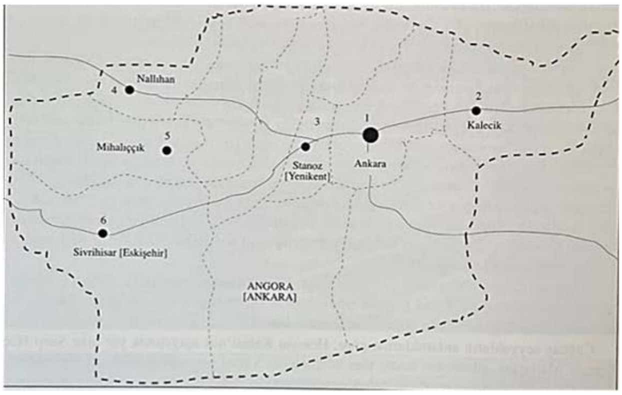


Figure 2. Ankara Sanjak-Osmanlı Arşivi Documents no: Y.PRK.KOM. 5.46_Hicri 29.11.1304 (1886/1887)

Currently, the urban protected area is within the borders of Sivrihisar town center and Sivrihisar Municipality. The Sivrihisar District Governorate, Sivrihisar Municipality and the Eskişehir Cultural and Natural Heritage Conservation Regional Board, due to its status as an urban site, are the institutions with priority authority for the management of the area. The urban protected area is within the borders of 11 (Camikebir, Cumhuriyet, Blacksmith, Elmalı, Gedik, Karabaşlı, Karacalar, Sword, Domed, Kurşunlu and Yenice) of the 13 neighbourhoods in the Sivrihisar district center.

3.1. Technologies Used for Recording Historic Buildings in Sivrihisar

For the purpose of learning to document historic buildings, Master students of FSMVU at field work of Conservation Studio I have recorded the selected historic buildings, including the Armenian Church and Mehmet Cavuş Han (inn*)*. Due to the different scales of the two buildings, in particular, the Armenian church which has more monumental scale rather than the han which is somewhat as house alike, it was decided to use laser scanning for recording Armenian Church while for han it was more appropriate to obtain 3D model (SfM) photos processed with Agisoft.

For both buildings a drone was used to obtain photos of top view and to have a particular record of its setting within the parcel and in relation to the neighboring ones.

3.1.1. Armenian Church in Sivrihisar – Brief History

The Armenian Church is located on a slightly sloping land in Kılıç neighborhood in Sivrihisar, at block no.159, parcel no. 1. To the north of the building is Muzaffer Atasoy Street and parcel no. 505 is used as the town park with a green landscape. The rest of the surrounding parcels have residential functions. Armenian community living here gained intensity with the Kantzag (now Girovabad-Ganja) and Arthsakh (Karabakh) Armenians who came and settled in the region at the beginning of the 17^{th} century. The Yerrortutyun Church was first founded in 1650 in the center of the Armenian quarter. It was rebuilt in 1881 by an architect Minteş Panayot according to the inscription on the west side entrance door after the Armenian quarter fire in 1876. In addition to the building inscription, the year 1881 is written in relief on the keystones of the upper row of window arches on the north, west and south facades. During 19^{th} century Armenian population contributed significantly to the development of cultural life. After 1915 the building lost its original function [10]. It is known to have been used as an electric power plant and a municipal warehouse for a while after losing its original function, and later was transferred to the Sivrihisar Municipality for 49 years with the protocol signed between the Ministry of Culture and Sivrihisar Municipality in 2001, and continues to be used as a cultural center after the restoration works completed in 2012. Also, it is among 156 buildings registered as protected of General Directorate of Churches, Antiquities and Museums.

3.1.2. Record of Armenian Church in Eskişehir

The following steps were made to measure and document the church using a 3D laser scanner, and to prepare precise plan and section drawings in the CAD.

3.1.2.1. Preparation

- Paper targets as triangulation points

For the purpose of the measurements to be made with the digital tachometer, the targets of 14cmx14cm sizes paper are used to determine the common points (TiePoints). These are required for the registration of each scanning position (ScanPos) which are needed in order to create the Point Cloud model of the Church.

- Establishment of necessary stations

As the scanning positions increase and change places for the purpose of data collection, the measurements made with the Digital Tachometer should follow the new positions to be measured. Therefore, for new stations to be established, either the coordinates of the previous paper markers are used, or a new station is established with known coordinates.

- Binding precision of scanning positions

While each new station established with the digital tachometer is connected to the next station, the connection error between both positions is checked with the SCENE program to ensure the necessary measurement accuracy.

3.1.2.2. Measurements Made with 3D Laser Scanner

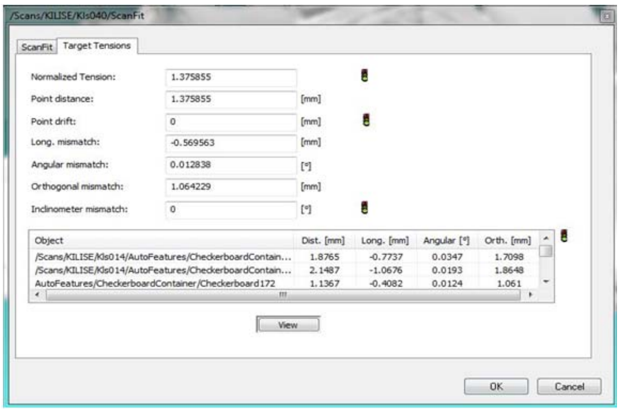
FARO FOCUS 3D S 120 laser scanning device was used to obtain the 3D point cloud data of the church. The scanning device, which can measure at a distance of 120 meters, with a resolution of 0.002º and a sensitivity of ±2mm, can also obtain photographic data with its 70M pixel integrated color camera.

Before starting the work, the laser scanner operator sticks the required and sufficient 14cmx14cm paper targets to the required places to see the laser scanner according to the data collection positions. These reflectors are glued using a reusable paste that never harms the structure.

- Data collection with laser scanner

The measurement of the church with a laser scanning device took 2 days. In these measurements, approximately 65 scanning positions and approximately 65X150 million 0.01º points were measured to create the Church's point cloud model.

Table 1. Connection Data of Scan Position 040


/Scans/KILISE/Kls040/ScanFit

ScanFit | Target Tensions

Normalized Tension:	1.375855	
Point distance:	1.375855	[mm]
Point drift:	0	[mm]
Long. mismatch:	-0.569563	[mm]
Angular mismatch:	0.012838	[°]
Orthogonal mismatch:	1.064229	[mm]
Inclinometer mismatch:	0	[°]

Object	Dist. [mm]	Long. [mm]	Angular [°]	Orth. [mm]
/Scans/KILISE/Kls014/AutoFeatures/CheckerboardContain...	1.8765	-0.7737	0.0347	1.7098
/Scans/KILISE/Kls014/AutoFeatures/CheckerboardContain...	2.1487	-1.0676	0.0193	1.8648
AutoFeatures/CheckerboardContainer/Checkerboard172	1.1367	-0.4082	0.0124	1.061

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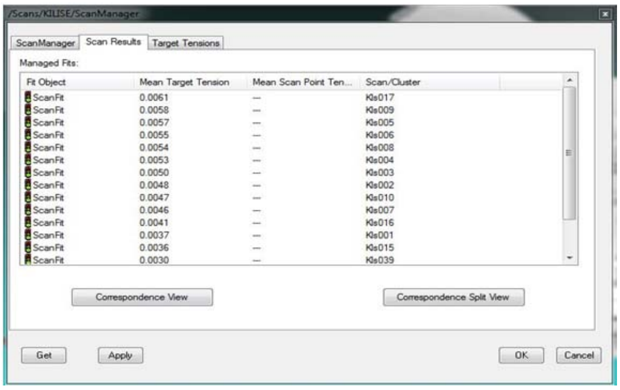
Table 2. Connection Data of Different Scan Positions


/Scans/KILISE/ScanManager

ScanManager | Scan Results | Target Tensions

Managed Fits:

Fit Object	Mean Target Tension	Mean Scan Point Ten...	Scan/Cluster
ScanFit	0.0061	---	Kls017
ScanFit	0.0058	---	Kls009
ScanFit	0.0057	---	Kls005
ScanFit	0.0055	---	Kls006
ScanFit	0.0054	---	Kls008
ScanFit	0.0053	---	Kls004
ScanFit	0.0050	---	Kls003
ScanFit	0.0048	---	Kls002
ScanFit	0.0047	---	Kls010
ScanFit	0.0046	---	Kls007
ScanFit	0.0041	---	Kls016
ScanFit	0.0037	---	Kls001
ScanFit	0.0036	---	Kls015
ScanFit	0.0030	---	Kls039

Correspondence View | Correspondence Split View

Get | Apply | OK | Cancel

In the point cloud model created by linking the collected point cloud data, the optimized tensions error deviations of the scanning positions are distributed to all scanning positions in the formation of the pattern, thus increasing the precision at any point. The point cloud created in the church is colored by the photographs taken by the scanner.

For example, 4,000,000 point readings were made with the 040 (Kls040) scan position of the church, and this reading position was connected to the previously established stations and the project coordinate system using 13 different points with a standard deviation of 1.375mm (Table 1 and Table 2).

3.1.2.3. Evaluation of Collected Point Cloud Data (process) and CAD Drawings

After the completion of the field studies, the point cloud data of the church was processed in two stages and prepared for drawing in CAD.

For each scanning position read by the 3D Laser Scanning device, reading errors, connection errors to the project coordinate system, unreadable areas (blind spots) in the scanning area are detected and the found errors are corrected (Figure 3). Unreadable areas are completed in the next positions. After all the measurement work is completed, the data checked in the field are cleaned, colored, and poly-data and orthopoints (Figure 4 and Figure 5) are created with the help of high-capacity computers.

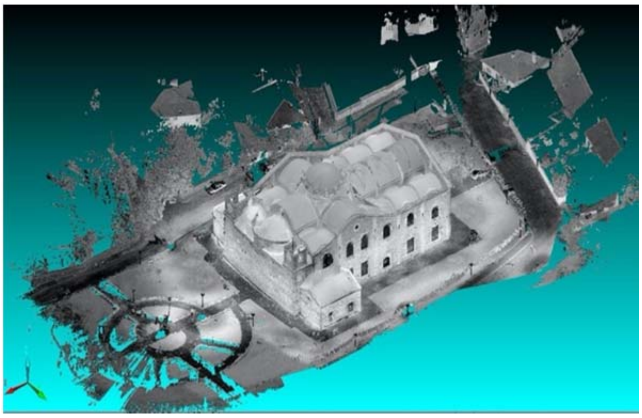


Figure 3. Dense point cloud 3D model

Figure 4. Section produced by 3D laser scanning model

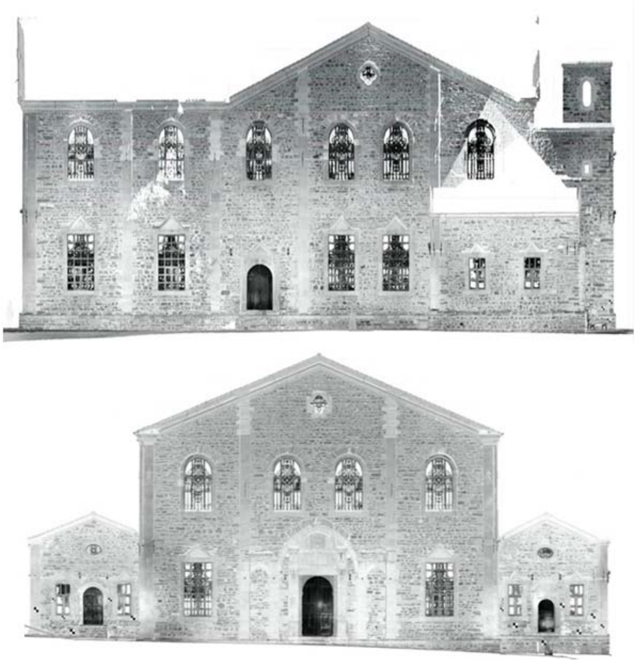


Figure 5. Facades produced by 3D laser scanning model

The next stage is the creation of CAD drawings (Figure 6) as a post-processing phase based on poly-data data obtained point cloud created with the church's 3D laser scanning device.

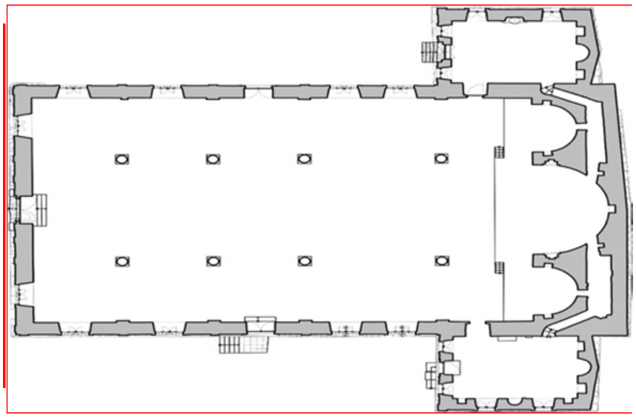


Figure 6. Plan drawing in CAD

3.2.1. Mehmet Çavuş Hanı- Brief History

Mehmet Cavuş Hanı (inn) is located in Sivrihisar, Kubbeli District, Yunus Emre Street, No: 6, at the island 195, in plots 22-23 across the Ulu Mosque. The building entrance is provided from the Yunus Emre Street, in particular the main entrance and three shop entrances. The Han (Inn) is set next to the adjacent buildings together creating street scape.

The inn has survived to the present day, but it has lost its original function and currently is used as a warehouse. The current owner of the inn is Murat Ünallı, a merchant, who bought inn in 2010 and started using it as a warehouse. From to the interview with Mehmet Akdemir, the previous owner of the inn, in October 2019 the oral history of the inn was learned. Mehmet Akdemir, is the grandson of Onbirlerin Mehmet Çavuş, who built the inn and managed it. According to Mehmet Akdemir's statement, in the period when foundation properties began to be sold to the public, in 1937, İrfaniye Madrasa was purchased by Mehmet Çavuş. By using the materials of the İrfaniye madrasah (school) a house in Kurşunlu neighborhood, the inn was built in 1939-1941.

Until 1987, the inn was operated as the New Hotel by Mehmet Çavuş's daughter Bircan Akdemir and her husband. After the inn was closed, it was used as warehouse for cheese production.

3.2.2. Record of the Han in Sivrihisar

For the Han in Sivrihisar it was decided to obtain 3D model from high resolution photographs including the top view taken with drone. The model was prepared for both interior and exterior. The metashape of the Han in particularly photogrammetric processing of digital images and 3D spatial data generation were made using software Agisoft. When dealing only with software for the best results of the product it is important to have well established photo taking system as showed in Figure 7. Photos are taken from different angles with known focal length and supporting control points.

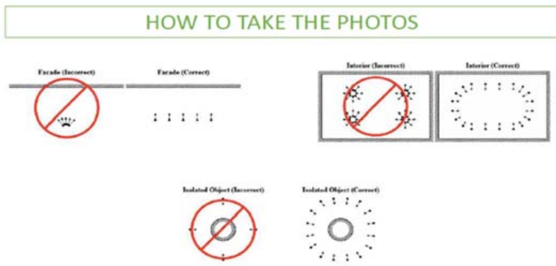


Figure 7. Photo taking system

For the Han 1572 photos were used and imported in the Agisoft, afterward the calibration tool was used. Further steps included aligning photos to produce tie points (Figure 8). For better result, the dense could was built choosing proper options under workflow which in the end gave contour of real 3D model (Figure 9). Finally, to obtain bumpy 3D model it was also needed to use option build mash and with option build texture the final 3D model was produced (Figure 10).

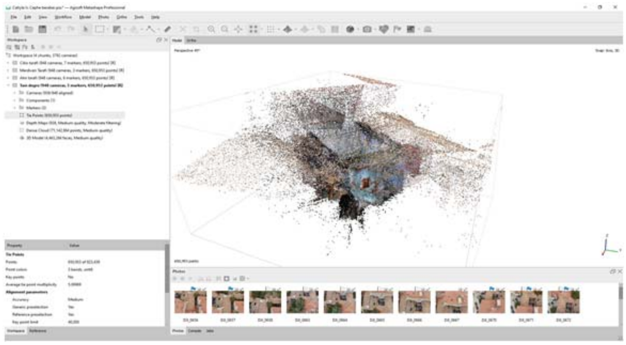


Figure 8. Tie points

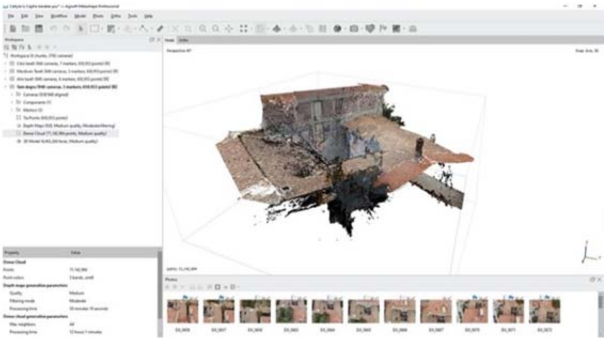


Figure 9. Dense cloud

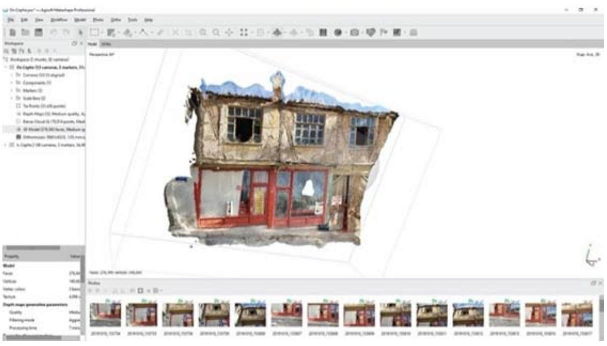


Figure 10. 3D model

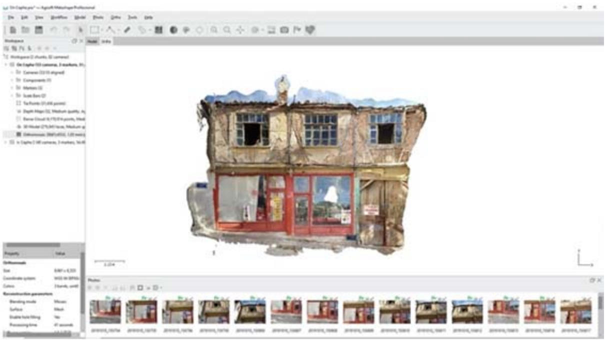


Figure 11. Orthopoint

- Preparation of CAD drawings (post processing)

Before it is ready to draw the building in CAD the targets should be added to create scale (eg, in both directions distance from points) and using measures from points. After this step, the scaled model was ready to obtain orthophotos (Figure 11). The produced photos were then imported to CAD with good resolution and rechecked to control if they overlap the dimensions taken on-site (Figure 12).

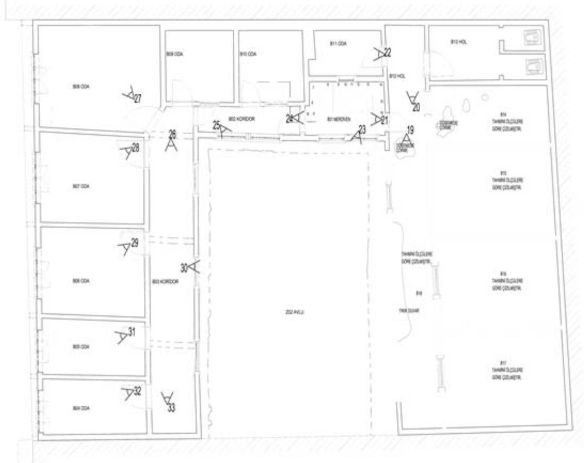


Figure 12. CAD plan drawing following photo-based model

4. Discussion and Conclusion

The professionals dealing with built heritage preservation in the first place should be able to understand the structure and proceed with surveying and assessment. A detailed and accurate surveys of historic structures require good knowledge and basic steps from photo record, preparing outlines, taking measurements in situ, followed by inspecting current building condition and state of conservation, and etc. Traditional surveying techniques using traditional tools may provide a good understanding of the building and context, and it is less expensive while there are also disadvantages such as missing details and possible mismatch of measurements, long days of on-site work, and difficulties in measuring high elevations or inapproachable areas. Thus, applying solely traditional surveying techniques may result in absences of some important information and thus cause negative effects during decision making phase.

The new advanced technologies have helped to overcome most of the issues which were constantly present in the field work, such as time limits, record of inapproachable areas, record of high structures and roof, ruins and in final thorough record of details and structure in total. The record itself may be provided by using 3d laser scanner or simply with digital photos providing 3D model and thus orthophotos.

In brief, advantages of laser scanners and photogrammetric technique can be defined as provided detailed record, short recording time, produced 3D model, sections and plans with thickness, and it is easy to work with. Among the disadvantages of laser scanning and photogrammetric techniques are post productions (point cloud to model) require special knowledge and added time, and on-site record depends on weather conditions. Furthermore, photogrammetric models need to be rechecked using a more precise measurement tool, such as a laser total station, or in our case, a terrestrial laser scanner, to obtain more accurate results.

In both cases obtained records are accurate and produced orthophotos are ready to be used in CAD software for further drawing productions. Even though for both structures discussed within this paper it was possible to do record by either of principles, due to time constraint digital photo software (Agisoft) was used mainly for the han while for the church terrestrial laser scanning was more efficient.

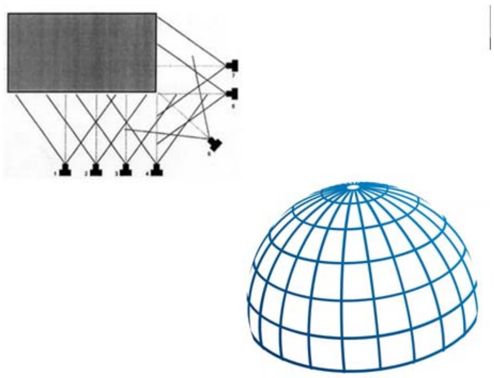


Figure 13. How to take photos for a photogrammetric survey which overlap each other and form a virtual sphere around the object

The nature of buildings in subject helps professionals to decide which technologies would be appropriate. In case of the showed examples the church's roof top reaches 21,56m, while of han (inn) it is 6,30m. Therefore, using photogrammetric method in church would be rather more time consuming since the walls are high and for a successful photogrammetric survey the photos should be taken with the minimum distortion and minimum need to correct perspective. The high interior walls of the church would create a negative point, and more time would be spent and also a monopod would be necessary for higher levels (Figure 13). Certainly, the windows under the roof were documented with the help of a drone, since also for the laser scanner for these windows it is not possible to make a full scan from the ground level, the uppermost parts of the walls would have deficiencies in the cloud data. Whereas the han is composed of many smaller units set around an inner courtyard. In the case of terrestrial scanning, it would be necessary to scan all the rooms, one by one and register the scans with each other which would create an immense big digital data which also requires longer hours for postproduction. Therefore, photogrammetric survey was appropriate choice to provide a complete model of the han. For the entrance facade and the inner courtyard only two stations were used for 2 scans with terrestrial laser scanner to make a precise connection of outside and inside and to check with the accuracy of the photogrammetric model. In addition to these a drone was used for the roof model. In final, a combination of three techniques predominantly using photogrammetric survey was used for the documentation of the han. For the church drone for the highest parts of the walls inside and for the roof were used too. Apart from these high-tech methods, conventional tools such as profile gauge or contour gauge, tape measure were used for the details of the joinery.

Finally, within these educational case studies, the master students had a chance to see authentic details in a central Anatolian town and experienced combination of different techniques for the documentation, and surveying in particular of these. This site work in Sivrihisar provided them with the knowledge and experience of working in different media, solving problems on-site, overcoming the constraints of time, learning to work in a team, and using different techniques according to the needs of the structure to be documented.

Acknowledgement

This paper used material prepared by master students at Fatih Sultan Mehmet Vakıf University, Master study in Conservation, at the Conservation project studio 2019-2020 Fall Semester, supervised by Assoc.Prof.Dr. Mine Esmer (coordinator), Assoc.Prof.Dr. Lana Kudumovic, Assoc.Prof.Dr. Ömer Dabanli, Assist.Prof.Dr. Ruba Kasmo and Dr. E. Selcen Cesur. We are thankful to our students who worked in the studio: Birgül Kurtçu, Cihan Yildirim, Şule Yildirim, Zeynep Aytekin, Belkis Bahar Alparslan, Dilara Nil Özocak, Muhammed Çolak, Shrouq Tkrory. Cihan Yıldırım was responsible for terrestrial scanning, drone documentation, and their postproduction. And Muhammed Çolak was responsible for the photogrammetric survey, and its postproduction.

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