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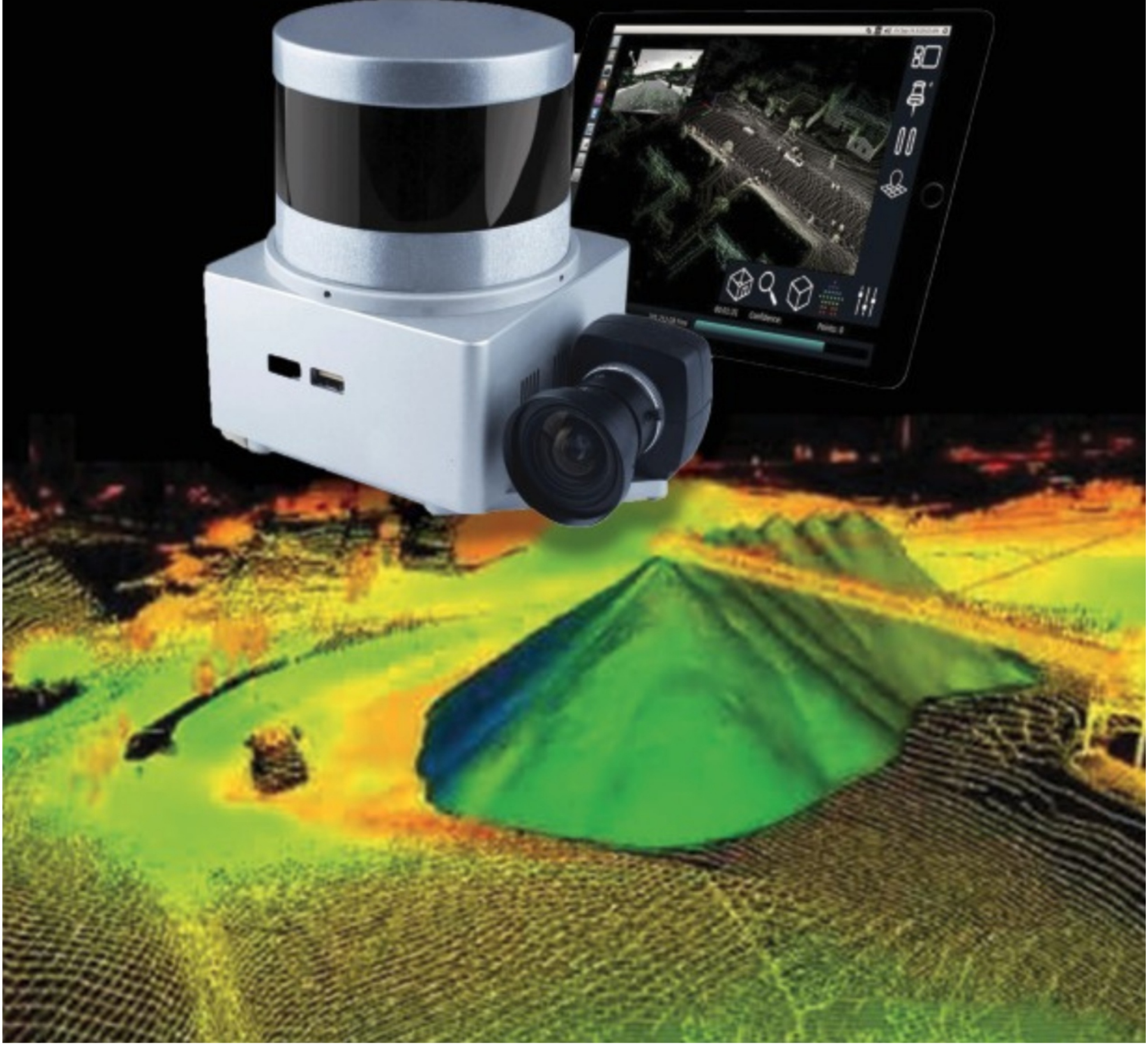

Advanced LiDAR

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- To provide an easily accessible and wide-ranging discussion environment that will strengthen and accelerate the sharing of knowledge and experience between scientists, researchers, engineers, and other practitioners who are involved in direct or indirect activities with the following topics.
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Contents

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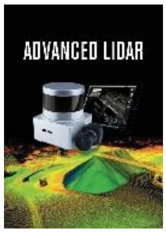

Advantages and Disadvantages of Using TLS Techniques in Monumental Buildings; Darsiyak Yanartaş Monastery Archangel Michael and Gabriel Church Example

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Keywords
Lidar
Terrestrial Laser Scanning
Orthophoto

ABSTRACT

Monumental buildings are considered as a building group that includes many different types of buildings, such as mosques, churches, madrasas, caravanserais, inns, and baths, built for public use. Each of these buildings has spatial characteristics that vary according to the type of building, periodical differences and regional character. However, it is seen that the majority of these buildings have a plan setup consisting of small spaces that are articulated to a large and central space. Among the monumental buildings, one of the building types that show this central place feature is the churches. While the use of terrestrial laser scanning method in the measurements of churches with central space provides many advantages, it also causes some disadvantages. In this study, measurements of the Yanartaş Monastery Archangel Michael and Gabriel Church, one of the 19th century Kayseri churches, was made with a terrestrial laser scanning system for documentation studies and the advantages and disadvantages of this measurement system were conveyed.

1. INTRODUCTION

Scientific and technological studies continue to develop in many fields in the world and in Turkey. This development has been included in the conservation of historical buildings with the use of laser scanning methods. Laser scanning methods give more detailed, accurate and faster results compared to traditional methods. More detailed and accurate data taken in the survey works is a very important element for better conservation of the historical building. By processing the data obtained by laser scanning methods, 3D models can be created and digital shares can be made. In addition, detailed analysis studies can be carried out through the data obtained by this method.

Although the studies carried out in the field of conservation have developed and increased in recent years, it is not possible to protect and document the destroyed buildings. For this reason, buildings that are on the verge of extinction should be protected or documented primarily. It is seen that the use of these techniques is preferred especially in the documentation of monumental buildings. Within the scope of this study, in order to investigate the advantages and disadvantages encountered in the use of TLS (terrestrial laser scanning) techniques in monumental buildings, the documentation studies of the Archangel Michael and Gabriel Church, which used terrestrial laser scanning technology in the survey measurement studies and the stages of the survey and the processes of transforming the obtained data into vector drawings for documentation purposes will be discussed.

Archangel Mikael and Gabriel Church in Kayseri, which had a very large non-Muslim population in the 19th century, is a building located in the Yanartaş Monastery in the village of Darsiyak (Kayabağ) in the Melikgazi district. The church, which is on the verge of extinction due to abuse and vandalism, contains many cultural and social data from the period it was built. In order to conserve this building, as one of the first stages, measurement and drawing studies were carried out with the Yanartaş Monastery Archangel Mikael and Gabriel Church within the scope of survey studies. [1]

[1]This study was developed and produced from the thesis titled "Darsiyak Yanartaş Monastery 'The Archangel Michael and Gabriel Church' survey-restitution and restoration project" completed in 2021 by Res. Ass. Melikşah Koca under the supervision of Assoc. Dr. H. Hale Kozlu at Erciyes University Institute of Science and Technology.

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2. METHOD

2.1. Terrestrial Laser Scanning

Terrestrial scanning systems, which continue to develop rapidly in the world, provide the most accurate transfer of the current state of the building to digital. With this system, which aims to minimize the margin of error, measurements can be taken with millimeter precision and detail in difficult and dangerous work areas without having to return later (Gümüş, 2010; Yılmaz et al., 2012).

In terrestrial scanning systems, if a building with a large surface area or a complex plan scheme is to be scanned, the scanning process should be done more than once from different angles in order to get the data more clearly and accurately. After a scan is finished, the secondary scan is continued from the adjacent surface of the first scanned portion. This process is repeated multiple times. In this way, all surfaces of the building/surface are scanned by arranging different stations. These stations create common scanned surfaces with the previously scanned surface (Kaya, 2020; Orhan, 2016 & Yakar, 2016)

Terrestrial laser scanning processes may not fully meet the purpose in some cases. In cases where it is used in simple projects, the desired results may not be obtained in terms of time and cost. In short, before starting terrestrial laser scanning processes, it should be clarified what the scanning will be done for and the problems should be examined accordingly (Kaya, 2020; Yakar et al., 2010).

2.1.1. Pre-scan planning

Before starting the scanning process with terrestrial laser scanning, the scanning process should be planned. The planning of the scanning process in historical buildings is carried out by examining the spatial setup of the building. In addition, the scanning process is planned by evaluating door and window openings and surfaces that will cause reflection in order to prevent light bursts and reflections (Erdal & Hasan, 2021).

In the scanning process, point cloud data obtained from different stations should be brought together on a common coordinate plane. This common coordinate plane can be used as the coordinates used at the first station (Altuntaş & Yıldız, 2008; Alptekin et al., 2019)

In this study; The measurements taken by laser scanning method were used for the survey works of the Archangel Michael and Gabriel Church of the Yanartaş Monastery. The interior of the church consists of the naos, gallery, above the prosthesis and the diaconicon. In the exterior, there are narthex and facades. There are stairs that allow access to the roof from the place above the diaconicon in the church. In the interior of the church, light bursts occur in the laser scanning method, due to the collapse of the dome and too much natural light entering through the window openings. For this reason, the number of stations has been tried to be increased as much as possible indoors. Keeping the number of stations high also allows the accurate measurement of the naos, which has a large space. In addition, attention was paid to the establishment of stations on the stairs. The gallery surrounds the naos in a "U" shape. For this reason, a station has been installed in each nave of the gallery unit. Considering all this planning, it was deemed appropriate to establish 11 stations on the ground floor, 11 stations on the gallery floor, and 2 stations on the spaces above the diaconicon and the prosthetic. It is planned to establish 8 stations for the facades, 2 stations for the narthex, and 4 stations for the roof and terrace in the exterior of the church (Figure 1).

Figure 1. Stations used in scanning

2.1.2. Scanning process and preferred software

The angles to be used in surface scanning and the frequency of scanning vary according to the scale of the project. The angle of contact of the laser beams sent with the laser scanning method on the building surface is of great importance in terms of being clearer and perceptible if the architectural elements in the building are concave or convex (Temizer et al., 2013; Yakar et al., 2019).

The FARO Focus M70 brand device equipped with GPS (global positioning system) was used in the documentation of the Archangel Michael and Gabriel Church of the Yanartaş Monastery. In this way, data could be easily transferred to AutoDesk software. Obtained point cloud data were first transferred to AutoDesk Recap software. Unnecessary point data is cleared in this software. Then, it was transferred to AutoCad software with the "Attach Point Cloud" command and made ready for vector drawing. This method eliminates the use of different interface programs and allows the data to be edited directly by the last user (Figure 2).

Figure 2. FARO Focus M70 brand device

Documentation and photographing were done at 360 degrees horizontally and 270 degrees vertically. When necessary, sensitive scanning and photographing processes were carried out on certain areas and surfaces. With the measuring device, measurements are made up to 70 meters at each station. However, this interval has been kept to a minimum in order to obtain more reliable data. The measurement speed is 488000 points/second. The camera, which works integrated into the device, allows photography with a resolution of 165 megapixels. These photos can be obtained through the AutoDesk Recap program. It is aimed to make detailed measurements and photographs in and around the building by establishing 43 stations in total. AutoDesk Recap, Faro Scene and AutoCad software were used in the entire scanning process.

2.2. Yanartaş Monastery Archangel Michael and Gabriel Church Drawing Stage

The data processed with Faro Scene software were transferred to AutoDesk Recap software and unnecessary points were cleaned. Then this was transferred to AutoCad software with the "attach point cloud" command. The north-eastern part of the roof of the church building was measured with traditional measurement methods, as it was thought to cause problems in terms of security.

2.2.1. Plan drawings

In the documentation studies, the plan drawings of the building are made by cross-sectioning the 3D point cloud of the building. AutoCad software was used for this. The sections were first taken as slices and the walls were drawn. Then, the drawings of the sections appearing on the ground were made over the plane section. This process is repeated for all floor plans (Figure 3, Figure 4).

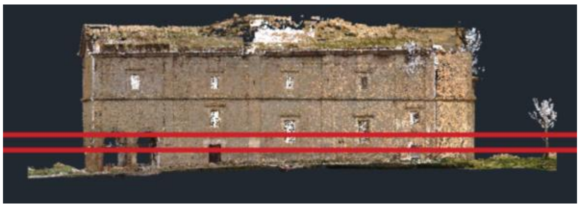

Figure 3. Plan section lines taken over the 3D point cloud

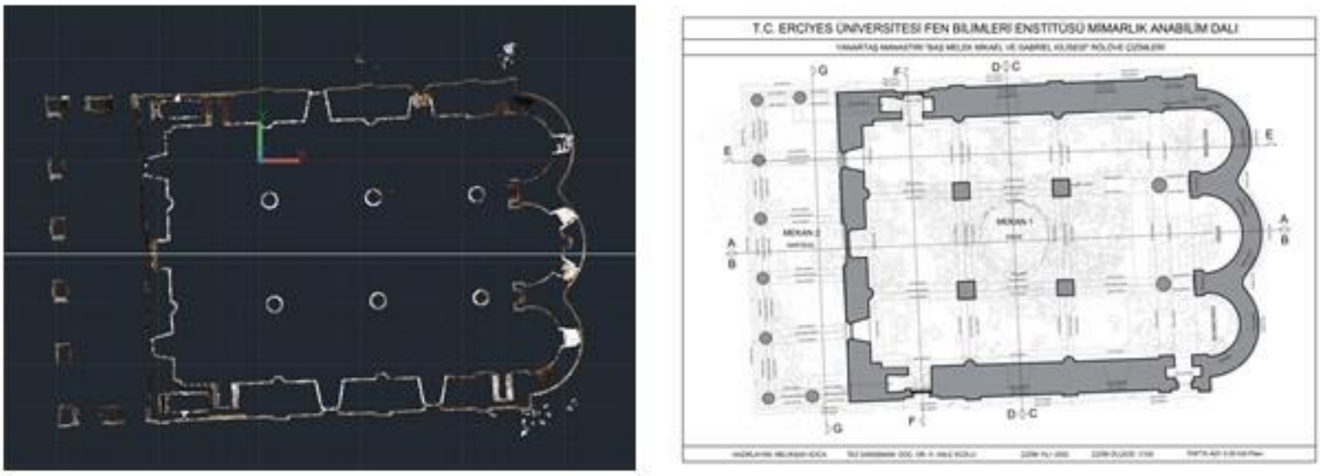

Figure 4. Point cloud slice plan section and drawing

2.2.2. Sectional drawings

In the documentation studies, the cross-section drawings of the building are made by taking vertical sections over the 3D point cloud data of the building. For this, the points to be cross-sectioned are marked on the point cloud data transferred to the AutoCad software and the cross-section is performed with "2 points". Then the "UCS" coordinate values are rearranged and the wall drawings are started by turning the slice into a section. The point cloud data is then made into a plane cross section to draw the visible segments (Fig. 5), (Fig. 6).

Figure 5. Section line over the 3D point cloud

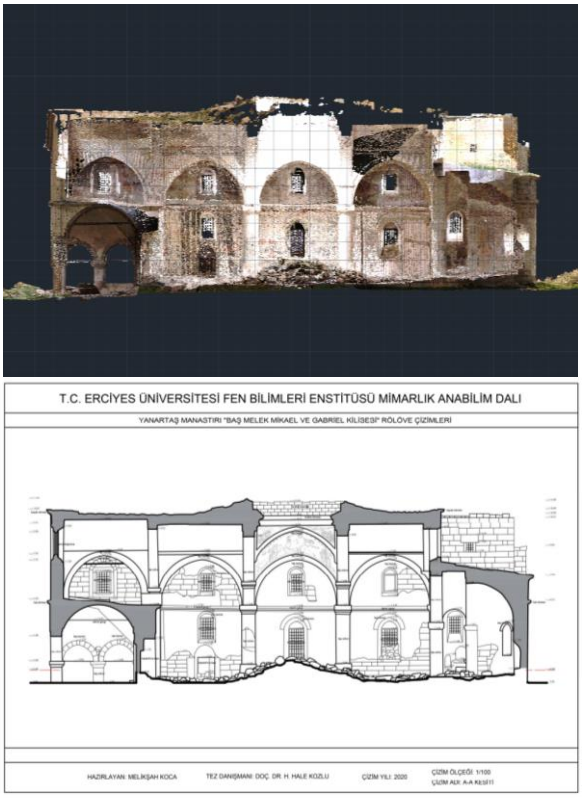

Figure 6. Point cloud plane section and drawing

2.2.3. Facade drawings

In the documentation studies, the facades of the point cloud data were studied in order to extract the facade drawings of the building. First, the point cloud is placed on the plane. Here, studies were carried out on the image that was optimized for the drawing by making changes on the point size, opacity and level of detail (Figure 7).

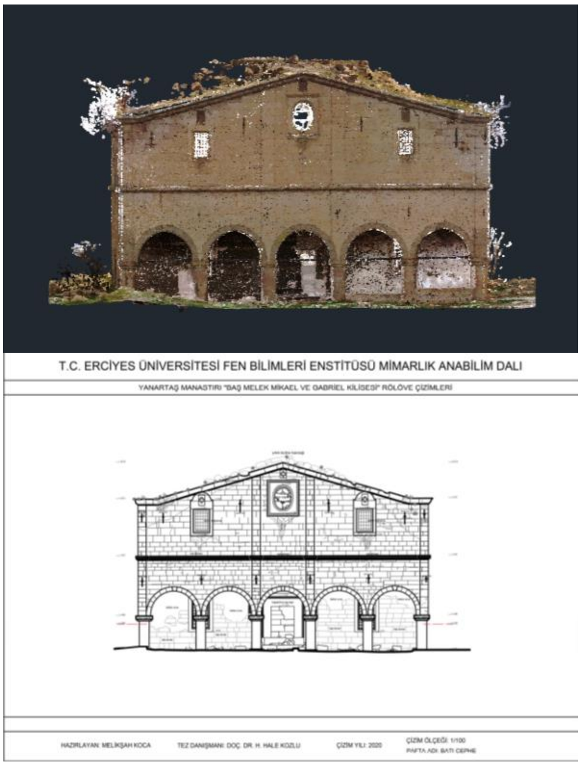

Figure 7. Point cloud facade and facade drawing based on this data

3. CONCLUSION

When the churches in Anatolia are examined, it is understood that central location feature is present in all churches despite their periodical or regional differences. The laser scanning method provides great advantages especially in indoor measurements, in such large spaces, and is preferred over traditional measurement methods in terms of time, labor, and detailed detection of structural elements and their deterioration. However, as in other monumental buildings, in other small spaces in churches, the subject of point shooting and scanning becomes difficult when the height and width of the space are very small. In such cases, it may be necessary to adapt the data obtained by different measurement methods to the drawing. In such measurement studies, the data obtained by traditional measurement methods can be easily integrated with the drawings extracted from laser scanning.

Another advantage of the laser scanning method is that it provides the opportunity to see and evaluate all the facades and spaces of the building together, thanks to the data obtained. Building details overlooked in the field can be easily read through point cloud data. In addition, it is possible to take a section from the desired point over the obtained point cloud data.

The fact that it contributes positively to the accuracy of the drawing by reducing the workload of documentation studies with the laser scanning method is an advantage that is valid not only for monumental buildings, but also for all types of buildings. In addition, measuring without touching the surface minimizes the damage to the historical building during the measurement. At the same time, these traditional buildings, which are under great destruction, pose a danger to those working in documentation studies. It has been experienced that the terrestrial laser scanning method is safer than traditional measurement methods. Many points are obtained with terrestrial laser scanning methods. The use of computers with high performance in the processing of these data will positively affect the data processing speed and the drawing stage.

In monumental buildings, where the structural integrity is conserved, the measurement process is more comfortable, in the event that some structural elements such as dome, roof and wall collapse, as in the church, which is taken as a sample, there may be too many light bursts around these openings. In this case, it may be necessary to supplement the building elements around these openings with traditional measurement methods. Again, as a disadvantage, if the FaroFocus device cannot be installed on the roof or in some upper floor spaces in case of structural problems, measurement may not be carried out by laser scanning method in these areas. Another disadvantage is that some wall paintings in the buildings do not give the desired result in orthophotos. In these cases, measuring, photographing and on-site drawing studies may be required by using equipment such as telescopic meters, binoculars, and ladders.

As a result, it is seen that the historical buildings that are our cultural heritage and that are not yet included in the conservation studies are rapidly disappearing. The ability to make fast and detailed documentation, especially in monumental buildings with terrestrial laser scanning method is considered as an important technological development for such buildings that are under the threat of extinction.

Author contributions

Melikşah KOCA: Case Study Survey, Software, Data curation, Writing-Original
Hale Kozlu: Conceptualization, Methodology, Writing-Reviewing and Editing, Investigation

Conflicts of interest

The authors declare no conflicts of interest.

Statement of Research and Publication Ethics

The authors declare that this study complies with Research and Publication Ethics

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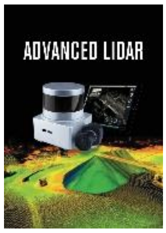

Survey Process of Gesi Pigeonry with Ground Laser by (Point Cloud) Scanning Method

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Keywords
Lidar
Gesi Pigeonry
Laser Scanning
Point Cloud

ABSTRACT

The pigeons, which are accepted as the symbol of peace and love, are one of the first domesticated birds by people. Pigeons have been bred up for 6000 years since they are used in postal services, feeding as a hobby, benefiting from meat, manure, and egg for different purposes. There are special pigeon nests made for pigeons in the world. The nests in the Kayseri Gesi Region, which are described as a dovecote, are special structures that are unique in the world and are designed to obtain the pigeon manure used in agriculture. The unique feature of the gothic cavern is that the main nest is made of carved chambers under the ground and on the ground a dovetail chimney, a dovecote or a dovecote tower. As it is seen in this study which is related to dovecotes, it has the function, form, and organization of each other with its unique local artifacts. However, in the globalizing world, the necessity of adding the original identity of the dovecotes to the world cultural heritage is determined. Preserving cultural heritage is an imperative task for all civilizations in the world. In order to keep the traces of civilizations alive, it is extremely necessary to transfer historical and cultural artifacts from generation to generation. Terrestrial laser scanning method has become the reason of choice for many disciplines with its potential to obtain cost-effective, high-accuracy data in a short time. Laser scanners, which ensure that architectural documentation works are carried out in a healthy way and in accordance with the determined standards, have become preferred by users in our country and in the world. Different from traditional methods, terrestrial laser scanning method was preferred for the preparation of survey projects of Gesi dovecotes. Terrestrial scanning device has replaced traditional measurement methods with the rapidly developing technology. The laser scanning method has advantages over traditional methods in terms of speed, workflow and workforce. Using a laser scanner for accurate measurement allows accurate preparation of survey projects. By using local laser scanning technologies, thousands of points reflecting the object or object surface are obtained. With the help of these points, realistic 3D models are obtained. According to the models created, area, volume and surface dimensions can be reached according to the size information of the object or structure. 3D point cloud data about the plan scheme, sections and facades of Gesi dovecotes, which are of historical importance, were obtained by using Faro Focus 3d laser scanning device.

1. INTRODUCTION

Cultural heritage is one of the most important links between the past and the future of humanity. It has an important place in the individual and social development of human beings. It is also an important issue for humanity to leave these heritages to future generations in accordance with their original form. UNESCO (United Nations Educational, Scientific and Cultural Organization), ICOMOS (International Council for Monuments and Sites), ISPRS (International Society for Photogrammetry & Remote Sensing), ICOM (International Council for Museums), ICCROM (International Center for the Conservation and Restoration) of Monuments) and UIA (International Union of Architects) have undertaken duties related to the protection of world cultural heritage (Calegari, 2003; (www.unesco.org.tr, 2021).

The current situation and problems of cultural heritage are determined by metric, written and visual

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documentation. Documentation is one of the most important ways of transmitting cultural heritage to future generations and introducing it to the society, as well as providing basic data in all conservation studies aimed at solving the problems of cultural heritage. Today, different techniques are used in the documentation of Cultural Heritage, and these techniques are developing rapidly in the light of technological developments. The production of physical, social, economic, cultural and historical information of cultural heritage in various qualities and scales, and the processing of large amounts of data produced and transforming them into usable information are indispensable in terms of protection (Yakar et al., 2015).

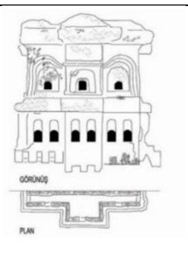
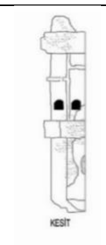
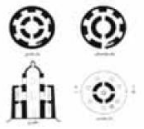
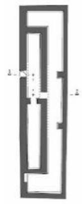
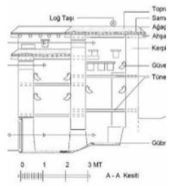
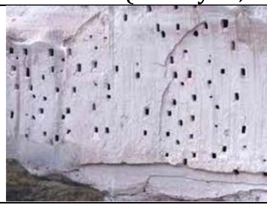
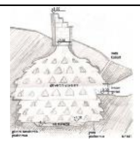
Terrestrial laser scanning method has become a more effective and up-to-date method than traditional measurement methods for architectural documentation studies. Terrestrial laser scanning technique is basically evaluated within the LIDAR (Light Detection and Range) system (Yakaret al., 2020; Ulvi & Yakar, 2014) is the name given to remote sensing technology (Sevgen, 2018). Using the 3D point cloud data obtained by the laser scanning method, the following studies can be carried out on CAD applications; basic measurement data, orthophoto image extraction, 2D or 3D drawings, solid surface models, 3D animations, texture covered 3D model extraction (Karasaka & Ulutaş, 2021; Yılmaz & Yakar, 2006).

In this study, the survey studies of Gesi Pigeonries, one of the historical and cultural monuments of Kayseri province, with terrestrial photogrammetry technique were examined. With laser scanning, 3D CAD drawings were created from high-resolution 3D point cloud data, and it was seen that measurements that can be a base for architecture, restoration, restitution, historical artifact documentation and registration are much more efficient, more advantageous in terms of graphics, and more sensitive in terms of accuracy than classical methods.

2. BIRD CULTURE, BIRD HOUSES and PIGEONS

Pigeons, one of the first domesticated birds by humans, have been bred for different purposes for 6000 years, primarily for use in postal works, as a hobby, and to benefit from their meat, manure and eggs. There are many nests and structures built for birds in the world, and most of them seem to have been built by humans as above-ground structures. According to the published literature, there are special pigeon nests in Iran and in our country in Cappadocia, Diyarbakir and Kayseri.

Table 1. Bird Lodge, Kebûterhâne, Boranhane, Rock Carved dovecotes and Kayseri dovecotes.

		
Bird Lodge Fatih Bali Pasha Mosque Bird Pavilion/ Plan, section, view drawings (Avunduk,2008)		
		
Iranian Kebûterhouses (Gavart Tower) (Amirkhani, Okhovat, & Zamani, 2010)		
		
Diyarbakir Boran Houses (Bekleyen, 2007)		
		
Nevshehir Cappadocia rock carved dovecotes (Berkmen, 2015)		
		
Kayseri Dovecotes (Büyükmıhcı, 2006)		

The formations defined as dovecotes in Kayseri Gesi Region, which is the subject of this research, are special structures in terms of their architectural features and are designed to be used in agricultural areas by obtaining pigeon manure. The feature that distinguishes the dovecotes in Gesi from their counterparts is; it is a stone-built structure form that creates the main nest by transforming the rocks into carved rooms in the underground part and forming the nest door called the dovecote chimney/pigeon bush or pigeon tower seen above the ground (Figure 1-Figure 2).

Figure 1. Pigeon bush and underground nest (Albayrak, 2019)

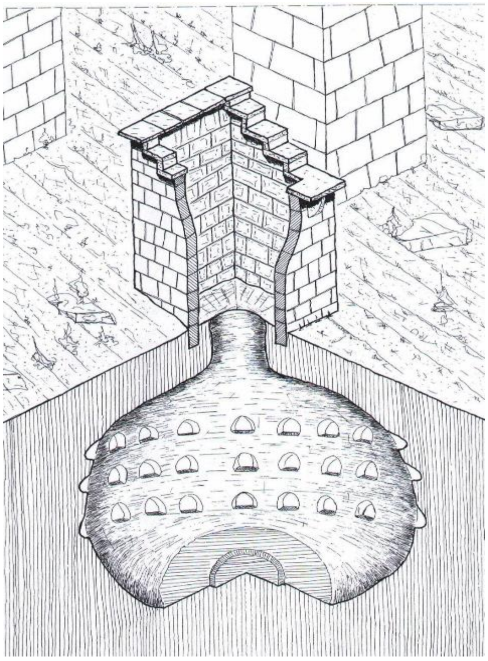


Figure 2. Cross-sectional perspective (Dr. Lecturer Mustafa Korumaz Personal Archive, 2002)

Along the roads leading from Gesi to Kayabağ (Darsiyak) and Güzelköy (Nize), dovecote bastions can be seen in different forms, first sporadically and intermittently, then lined up one after the other. These bastions, which are positioned according to the slope of the land and sprinkled on both sides of the valley, on the right and left, under the roads, exhibit an impressive appearance. The visible upper part of the pigeonry is called a chimney/bush or tower, and it is kept high in order to protect the pigeons from the environment factors (the chimneys are kept high to protect the pigeons from reptiles and insects that can harm the pigeons (Büyükmıhcı, 2006) and that can harm the birds (marten, fox, wolf, bear) is the part that protects from all kinds of creatures. Pigeon house chimneys are the mouth part that sits on these nests and allows the birds to enter and leave their nests (Büyükmıhcı, 2006) (Figure 3). The dovecotes, whose nest part is not perceived from the outside, have only towers in the landscape, and the towers are in harmony with the slope of the valley (Özkul & Özkul, 2021; Alptekin et al., 2019) (Figure 4).

Figure 3. Bushes and birds (Albayrak, 2019)

Figure 4. Harmony of the valley and the dovecotes (Albayrak, 2019)

The parts of the masonry forms rising on the land today, which connect the pigeons with the building and are designed to function as a door, are raised above the ground like a chimney to illuminate and ventilate the interior, and their roofs are raised approximately 3.00-5.00 meters from the ground level and are aligned with the valley slope. Their angling in the plane is obviously intended to facilitate the entry of birds.

In very few examples, the heights are approximately 6.00-7.00 m. has also been found. The underground sections, which are designed for the purpose of the pigeons living safely and for the easy collection of their manure, which is a very important commercial tool for the period, can be descended into and, according to the remaining examples, a water pool in the center of the ground, a bait platform around it and a pigeon manure accumulation on it. The other consists of a platform and niches where pigeons nest; This section under the ground can be reached by a narrow tunnel that a person can easily enter and exit through, and in some examples, the presence of an inclined bait channel can be detected on the soil surface. In the few examples that can be entered, the depth of the main nest section is 5.00-7.00 m. between them was found. In some examples, it is understood that the original plastic masonry walls, which were destroyed over time, were made later in the form of period additions made of rubble stone.

There are pigeon nests at a depth of 20-30 cm on the walls of the main nest. These cavities are also called slots and swaps. Slots and swaps are used for laying and sheltering pigeons (Özkul & Özkul, 2021).

'These individually carved nests are quite safe for pigeons. The geometrical connection between these slots is really interesting. So much so that no pigeon nest is located on the axis of the other nest. In the settlement, the axis has been shifted in the nests and care has been taken that no pigeon contaminates the other pigeon or its nest. The slots that catch the same axis in the second row do not harm each other due to the concave slope created on the wall' (Büyükmıhcı, 2006) (Figure 5).

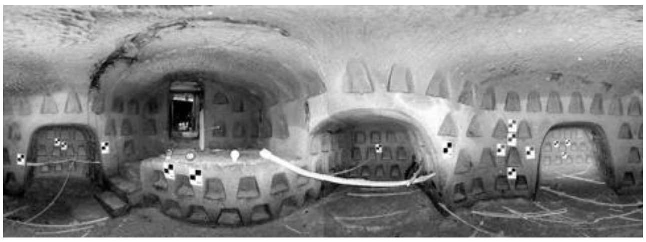


Figure 5. Slots and swaps (Albayrak,2019)

'Although these nests are used for laying and sheltering pigeons, the main purpose of the building is to collect pigeon manure, which is very valuable for the commercial conditions of the period. When we examine the nest structure, the association of this geometric chain and its design were made in accordance with this purpose. Pigeon manure is collected on the platform that surrounds the building. The relationship between the people who enter the building and collect these fertilizers in necessary periods is provided through a narrow tunnel (Büyükmıhcı, 2006)(Figure 6).

Figure 6. Nest entrance tunnel (Albayrak,2019)

The necessity of adding pigeon houses, which have unique local characteristics in terms of function, form, material, context and organizational relationship with each other, to the world cultural heritage with their unique identity in the globalizing world has determined the purpose of the study. Fieldwork was carried out in the valley where 147 dovecote entrance structures (bastions) and an accessible nest section (cave) are located.

2.1. The Purpose, Importance and Method of the Study on Gesi Pigeonries

The cloud method is used in the survey, restitution and restoration projects of historical buildings of various scales that need to be protected, or in the documentation of cultural and natural heritage sites, and is a method widely used by many architectural offices in Turkey and around the world (Uzun & Spor, 2019). Laser scanning technologies are used in engineering applications (Larsson & Kjellander, 2006), in the examination of changes in structures, in deformation measurements (Riveiro etal., 2011), in documenting cultural heritage structures such as mosques, baths, churches (Allen, Troccoli, Benjamin, & Murray, 2003), (Yastıklı, 2007), (Ergincan et al., 2010), measuring castles (Grussenmeyer et al., 2008), creating street silhouettes on an urban scale and street rehabilitation (Varlık, et al., 2016), bridge (Varol et al, 2018), geographical and geological applications such as caves and land surveying (Dunning, Massey, & Rosser, 2009), determination of forest and woodland parameters (Akgül et al., 2016) etc. appear in the fields.

Gesi dovecotes consist of 147 independent dovecote bastions and nests, and it has been concluded that laser scanning is the most suitable method for the survey and restitution projects of those bastions and nests. With the use of this method, the actual location of the current situation of the pigeonries, depending on the geographical coordinates, was obtained by the point capture method and transferred to the digital environment. It is ensured that the most intricate, complex and intricate geometries of the nests that can be entered are revealed exactly, and this method adds a positive value in terms of acceleration and accuracy of the process-result relationship, especially in the preparation of the restoration projects of the dovecotes. The technical objectives of the project are to take the surveys of the nest sections of the dovecotes, which are under the ground, to reveal the unknown features about the structure, and to prepare the original plan scheme. The main functional purpose of the project is to bring the historical richness of the region to light, to bring the region to country and world tourism, to integrate the people with the historical texture and to ensure the sustainability of the conservation awareness.

The first laser was developed by Theodore Maiman in 1960, and air and ground laser scanning was developed in the 1970s, and these scans are based on the Lidar4 technique (Reshetyuk, 2006). Commercial use of terrestrial laser scanners coincides with the end of the 1990s (Karasaka, 2012). Terrestrial laser scanning method scans the object and acquires millions of 3D point data quickly and reliably. Thanks to this scanning method, the surface geometries of cultural assets can be obtained no matter how complex they are (Alshawabkeh, 2006). The point cloud is obtained by scanning the structure as a series of points horizontally and vertically at a targeted angle (Altuntaş & Yıldız, 2008).

The beam coming out of laser scanners with horizontal and vertical rotating mechanism comes out of the electronic unit of the instrument and hits the optical part that rotates at a great speed (Figure 7)

Figure 7. Scanner, Optical and laser

The beam on the surface of this optical unit, which acts like a mirror, is reflected and exits the instrument at a special angle. Immediately after the laser scanner achieves this angle, it rotates around the vertical axis with a very small angle to obtain the next angle (Kuçak et al., 2014). The system converts the 3D point coordinates obtained through laser beams sent to the object to be scanned into digital data. The obtained digital data is transferred to the computerized drawing environment. Point data is converted into digital data by transferring the point image records obtained with 360 degree rotating camera angles to microstation and similar programs. It is then transferred to the CAD environment to be drawn in the drawing environment. Thanks to the views obtained through the photographic image recorded in the digital environment, floor plans, facades and sections of the whole building can be obtained.

2.2. Documentation Method of Gesi Pigeons with 3D Laser Scanning

The preparation of the survey-restitution-restoration projects of Gesi dovecotes started with 3D laser scanning. In the process of preparing precision plan and section drawings and documenting them with technical drawings, the following methods were used, respectively, in the Cad environment.

2.3. Relief Measurement Method with Laser Scanning and Structural Findings

Horizontal and vertical laser scanning measurements of the dovecotes were made to reveal the plan, section and facades. While drawing the plan, facade and sections, the walls of the dovecote bastions, nest entrances, swaps in the nests, human entrance gates, manure storage platforms, feed platforms, feed tunnels, water pools, all stone patterns and spaces of the tower walls, planted areas, scanning results were obtained. It has been drawn in full using the 3D point cloud data obtained. It is very difficult to take measurements with traditional methods in both the bushes and nest sections of the pigeon houses, and even if a superposition measurement is made after manual measurement, the manual method of working has been abandoned due to the difficulty of testing the accuracy margin and the laser scanning method has been preferred.

2.4. Laser Scanner and Equipment Used in the Study

Thanks to the technical possibilities of the laser scanning system, manpower was used to a minimum. Within the scope of the study, measurement and documentation processes were carried out with the Faro Focus 3d 120 brand terrestrial laser scanning device. Faro Focus 3d 120 brand terrestrial laser scanning device has the technical features of scanning and processing 976,000 points per second between 0,6-120 m distances up to a distance error of ±2mm (Figure 8).

Figure 8. Faro Focus 3d 120 terrestrial laser scanning device

The device was installed in 815 different stations in the building area and the structure was scanned with the Faro Focus 3d laser scanning device. Device measurements took 32 days with simultaneous use of two laser scanners. In these measurements, the laser scanner also took the photograph. The bastions of all 147 dovecotes were scanned, and about 20 nests were entered and scanned. Other slots could not be entered. (Gesi Kayabağ Pigeonry repair and Valley Arrangement Project was carried out by Demirhanlı Agricultural Products Tec. Project Service Industry and Trade Ltd. (Master Architect Hatice Filiz SEZER and her team) under the control of Kayseri Cultural Heritage Preservation Regional Board.)

2.5. Measuring Technique and Process of Gesi Pigeon Houses with 3D Laser Scanning

The conversion of the digital data obtained as a result of the laser scanning process and laser scanning into survey drawings took place in 6 stages. In the first stage; in the planning phase of scanning positions; the number and position of scanning positions, the resolution and the project coordinate system of the scanning were determined. The position and number of scanning positions vary according to the position of the dovecote bush, the form of the bush, and the slope of the land. By installing devices in 815 different stations in the building area, the structure was scanned with the Faro Focus 3d laser scanning device and a point cloud was obtained (Figure 9). In the second stage; Thanks to the point cloud data obtained as a result of laser scanning, exact measurements of the dovecotes were obtained. The raw scan data obtained after the scanning process in the field were combined with the Scene 5.4 program, which was specially produced for the Faro Focus 3d laser scanning device. After the merging process was completed, the color was assigned to the point data in each coordinate from the photographs obtained with the integrated camera of the device. (For the processing of scan data, users have unlimited freedom of choice to leverage the software tools most useful for their workflow. Point cloud data captured with FARO Laser Scanners, FARO SCENE, FARO As-Built, FARO-BuildIT Construction, FARO Zone 2D, FARO Zone 3D or with various software packages, including 3rd party software such as Autodesk ReCap (paksoyteknik.com.tr, 2021). The point cloud data obtained in the third stage was exported in .pod and .rcp formats and converted into a format that can be used in Cad programs. In the fourth stage; The point cloud data obtained by using the PointCab 3.3 Program was transferred to the dwg environment as a 2D orthophoto. The purpose of laser scanning is to obtain orthophotos. "Orthophoto image; They are digital images in which errors caused by curvature, rotation and height difference are corrected and transformed into vertical projections (Yastıklı, 2007). In the fifth stage; 2 or 3 dimensional technical drawings, solid surface 3 dimensional models or material coated 3 dimensional models and animations are obtained from orthophotos.

Figure 9. Pigeon houses and established stations (Albayrak,2021)

Since the data was transferred to the digital environment correctly, there were no deviations from the drawings and measurements, and when viewed from the plan, sectional facade and directions, all the measurements were provided in the diagram. Since these exact measurements were obtained by scanning and overlapping the entire structure 360 degrees in all directions, one-to-one data were obtained for all stone bricks used in the building and their unit measurements. In the sixth stage; All original drawings are mapped with techniques suitable for the project, and the work is completed. The dimensional differences of the bastions and nests, which have different geometric forms, were analyzed separately, and two and three-dimensional original measurements of each space were obtained.

2.6. Point Cloud Model Data Collection

Point cloud is the digital points data obtained by sending the laser beams to the target in a structure or geographical area with a laser scanning device and sending millions of points to each m^2 by scanning the point cloud. An object or field is formed through linear surfaces that are formed by combining these points, whose coordinates are known in the x-y and z planes in the digital environment. The raw scan data obtained after the scanning process in the field were combined with the Scene 5.4 program, which was specially produced for the Faro Focus 3d laser scanning device. After the merging process was completed, the color was assigned to the point data in each coordinate from the photographs obtained with the integrated camera of the device.

2.7. Converting 3D Point Cloud Model to Technical Drawings in Cad Environment

The obtained point cloud data was exported in .pod and .rcp formats and converted into a format that can be used in Cad programs (Figure 10-Figure 11). (In addition, the point cloud data obtained by using the PointCab 3.3 Program can be transferred to the dwg environment as a 2D orthophoto.(Table 2)) By combining the 3D data from the orthophoto obtained by laser scanning, all structural components such as occupied empty spaces, material patterns, plaster voids are stored in the device memory visually and numerically. Three-dimensional data taken from piece by piece and from different points are combined with the registration method to create a 3-dimensional point cloud model of the area. Any number of sections, views and plans can be taken from this model at the desired elevation. Thanks to other utilities, models are converted to vector drawing. Numerous intermediate plans and sections of the building can be drawn by cutting the three-dimensional model obtained from orthographic photographs transferred to the computer environment at the desired elevation, both horizontally and vertically. By transferring these cross-sections to the Cad environment, plan sections and views can be drawn as technical drawings.

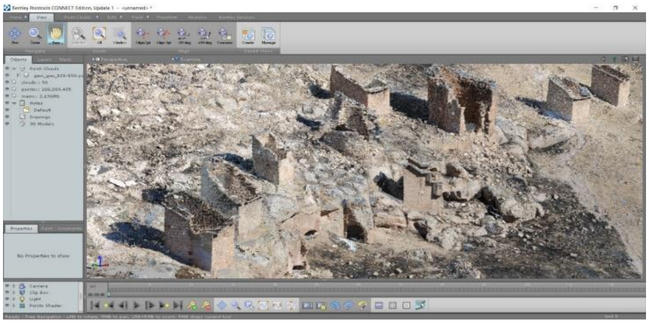


Figure 10. 3D point cloud model (Albayrak,2021)

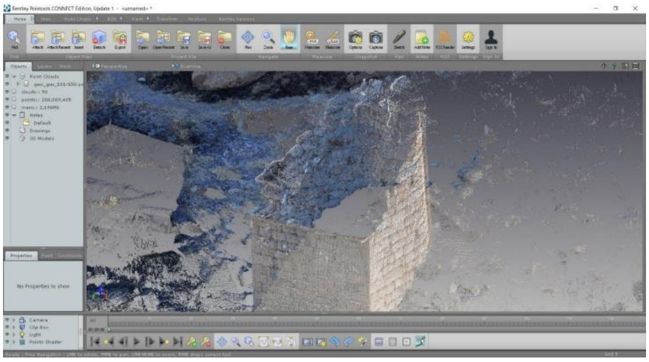


Figure 11. 3D point cloud model dovecote sign

Table 2. 2D point cloud model dovecote sign (the pigeonry number 141) (Albayrak,2021)

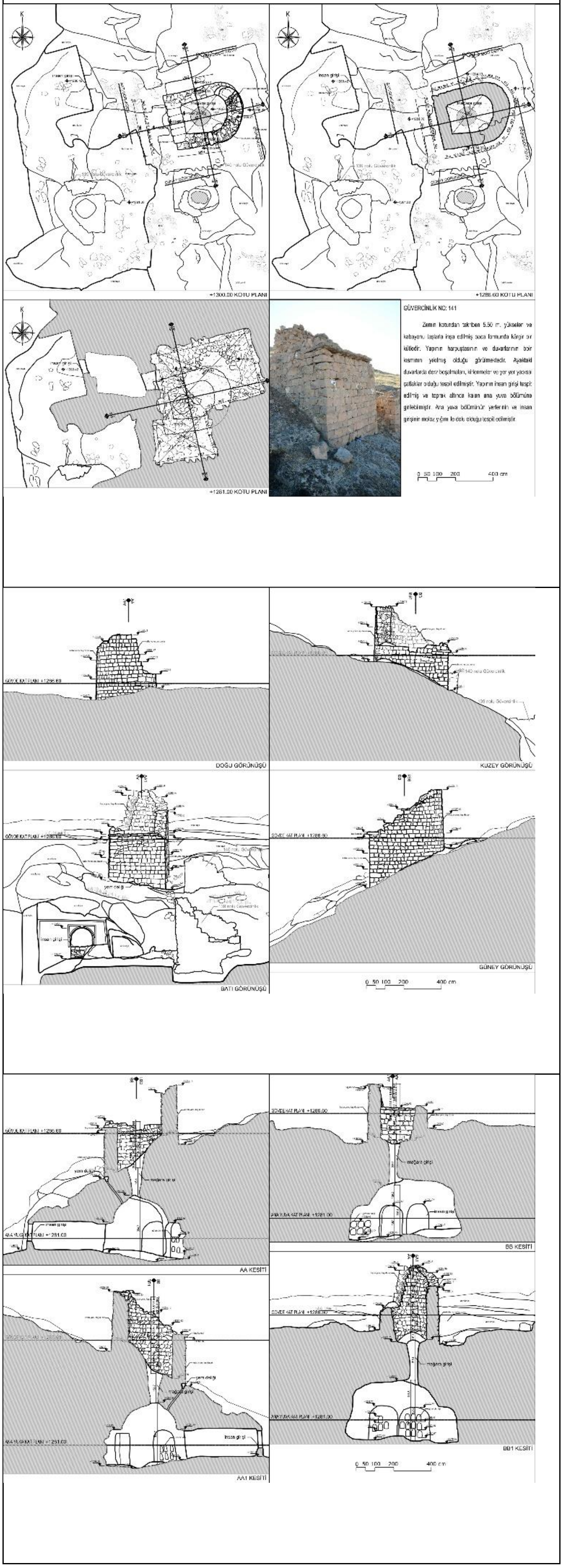
Obtaining these comprehensive images gives the technical drawing team the opportunity to process all stone pavement patterns, full-empty sections, existing texture and missing structural distortions, if any (Table 3).

2.8. Converting Data to Architectural Project

Based on the available data, a damage assessment plan, a damage assessment of the views, and a damage assessment map based on the sections were created. In the current damage assessment phase, digital damage assessment sheets were used in order to make accurate damage evaluation.

In CAD drawings where color separations due to full, empty and material differences are processed, differences due to material aging can be clearly seen in the colored areas on the layouts.

TABLE 3. The Survey of The Pigeonry Number 141 (Albayrak,2021)



3. GESI PIGEONRY MEASUREMENT DRAWING RESTORATION RESTITUTION PROCESS

3.1. Damage Determination and Architectural Deterioration

The main purpose of the preservation of historical artifacts is to protect the structural integrity of the artifact and to ensure its safe transfer to the future. The main aim should be not to spoil the original qualities of the historical artifact and to try to protect it without reducing the value of the document. I. Group Buildings, which are cultural assets, are generally large-scale public buildings owned by the state. The state protects such structures and makes the necessary interventions meticulously. But most of them are privately owned II. Grup Yapılar cannot be protected due to legal infrastructure deficiencies and various reasons (Örmecioğlu, 2010). Gesi dovecotes are privately owned, as stated before, and they were built during the Second World War. It is in Group Structures class. The deteriorations of these structures have been examined in situ and unfortunately some wear, damage and deterioration have been detected in these structures. Basically, it has been tried to analyze what kinds of destructions caused by various deterioration mechanisms, which are caused by natural causes and human effects, cause to the elements, sections and material types that make up the structure, and how these forms of destruction affect the protection status of the structure. As a result of the examinations made specifically for pigeons, it is possible to collect the factors causing deterioration under two main headings (Table 4);

1. Natural Factors
2. Human Factors

Table 4. Deterioration Factors in Pigeonries

1. Natural Factors	2. Human Deterioration
1.1.Mechanical Release and Discharges in the Joints	2.1. Faulty Repairs and Integrations
1.2. Material Deterioration	2.2. Human Caused Destructions/ Vandalism
1.3. Biodegradations	

3.1.1. Effect of Natural Factors on Deterioration

3.1.1.1. Mechanical Release and Joint Loosening

Fluctuations between night and day temperatures are the main cause of mechanical thaw. At high temperatures the material expands and at low temperatures it contracts. When this process repeatedly continues, the expansion and contraction movements begin to dissolve and crumble in the structure of the materials (Öcal & Dal, 2012). This mechanism can be seen in almost all inorganic materials used in the construction of dovecotes. Mechanical disintegration, which is especially effective in stone materials, causes physical destructions such as crumbling, shedding, rupture, and loss of parts following breakage. The number of pigeonries that encountered the problem of mechanical dissolution as a result of analyzing such deteriorations, which are seen intensively in Gesi pigeonries, is 130.

Of the 65 dovecotes, of which deterioration was detected on the tower wall, 49 of which were found to be damaged due to stone collapse, it is necessary to complete the demolished walls in accordance with their forms by using the traces from the building.

Discharges were observed in the joint material between the stones. It is likely that these micro spills have increased over time. Wind and climatic factors can cause this. Plant formation also causes joint discharge. It was observed that clefts were formed as a result of joint fall. These joint gaps and collapses, which can cause serious problems in the above-ground parts of the pigeon houses, were observed in 44 of the pigeonries, 6 of them require major repairs, the loose joints should be strengthened in accordance with their originality.

Joint discharge can also accelerate other deteriorations, as it will also affect the floor and ceiling surfaces of the stones to be exposed. In addition, the formation of salt crystals on the surface during the evaporation of water and the transportion of salts contained in porous materials to the surface with water is called salinization (Hasbay & Hattap, 2017). Salts cause damage to the joint filling and deterioration of the visuality of the towers.

3.1.1.2.Material Deterioration

As with all building materials made of rock, pigeon houses are also affected by water when they come into contact with it. For this reason, color change and salinization were observed in the materials. Particularly, such degradation was observed in the capstones exposed to rain. Pigeons cause melting of the materials in the capstones with their acidic feces. There are 140 dovecotes with discoloration in the material, 45 of which require major repairs. Color change, dirt accumulations should be cleaned with low pressure atomized hot water (nebulization), washing should be supported with a bristle brush. Where this technique is not sufficient, cleaning should be done with controlled sandblasting.

3.1.1.3. Biodegradations

Particularly, biological degradation has a great impact on the degradation of the stones of pigeonries. While lichens often form crusts and pits in the stone, bacteria-fungi cause exfoliation, animals-insects-birds cause typical shaped holes, rust and cracks. Biological deterioration of the stone may develop due to the pressure created by the growth of the organism and its progression to the inner surfaces (Hasbay & Hattap, 2017). In particular, the growth of the roots of advanced plants in the cracks by penetrating the stone can cause physical damage to the stone surface. During the succession of humid and dry seasons, fragmentation and crumbling may occur. Thus, the stone surface becomes susceptible to further colonization and biological growth.

In some cases, the organism may choose the stone surface as a feeding area and damage the stone and a chemical reaction may occur. Moisture occurs on damp surfaces. This causes accumulation and contamination on the stone surface (Öcal & Dal, 2012).

Contamination from algae, mold, fungus and algae on the building surfaces due to humidity was observed in 78 of the dovecotes. Algae, which cause more superficial damage to the stones, can in some cases crack the stone by wrapping their roots deep into the stone through cracks. Many algae require light for photosynthesis and therefore thrive where both light and water are present. Plants can develop by growing inside the structure with their roots. It causes cracks and crevices in the structure. Plant roots also cause chemical dissolution with the secretions they produce. Grass or perennial plants adapt into the pore system of the stone and cause mechanical cracks and ruptures in the stone over time (Hasbay & Hattap, 2017).

There are 30 dovecotes in pigeon-hole towers, especially in the coping, that need to be repaired depending on the biological deterioration and this type of deterioration. Cleaning is recommended for plants and biological formations in joints or on building surfaces, and chemical intervention is required for contamination from algae, mold, fungus and algae on building surfaces.

3.1.2. Human Caused Deterioration

People can damage structures consciously or unconsciously. They can cause deterioration in historical buildings and materials in various ways such as abuse, faulty repair, neglect, abandonment.

3.1.2.1 Faulty Repairs and Integrations

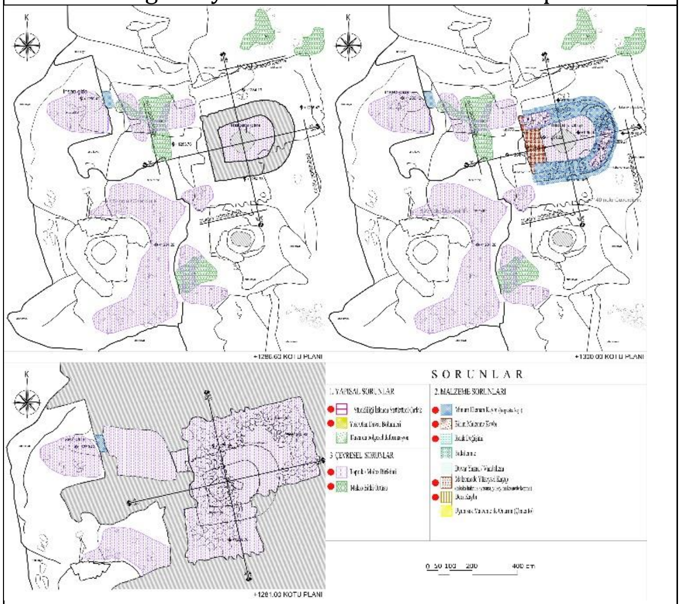
It has been observed that cement-containing mortar is used in the repair of pigeon houses. Compounds such as silica and calcium carbonate in the cement-added mortars used in the repair penetrate into the original materials of the building, causing crust formation on the surface, with the effect of water and humidity (Hasbay & Hattap, 2017). Atmospheric pollutants also support this process, facilitating the formation of crusts. The dovecote owners who wanted to repair the towers whose dovecotes were destroyed or partially damaged, unconsciously used cement-added mortar in 25 dovecotes. Cement applications should be removed from the pigeonholes.

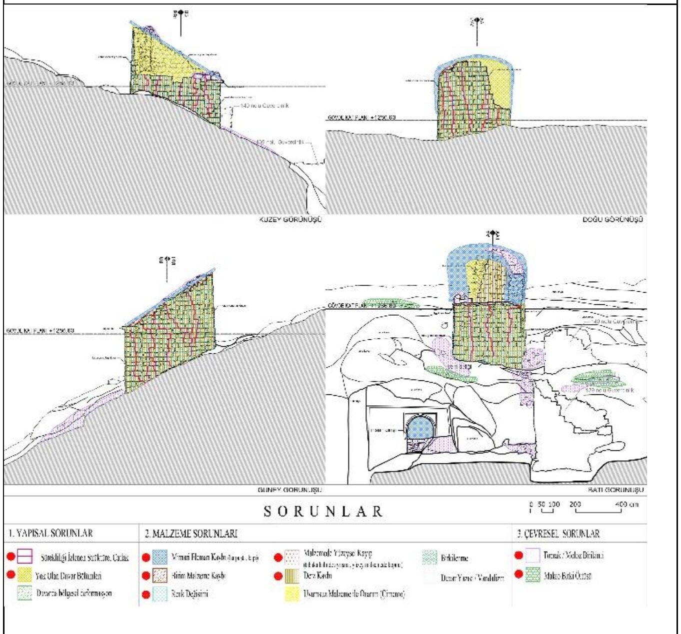
3.1.2.2. Human Caused Destructions/ Vandalism

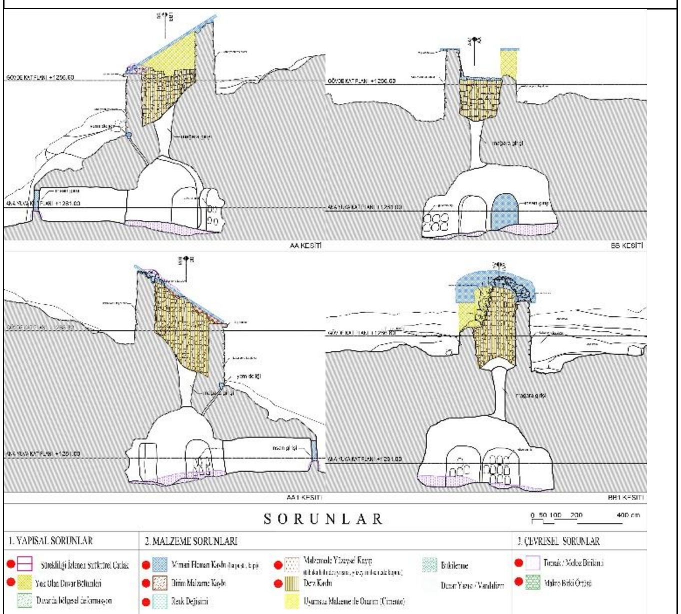
In some of the dovecotes, collapses on the stone walls were detected. The biggest factor causing damage in pigeonries is human. The majority of the collapses are caused by people. Significant deterioration has been observed due to reasons such as misuse and neglect, vandalism. Some dovecote bastions were destroyed by man for theft, and the stone walls were partially or completely destroyed. Pigeon bushes have been subjected to vandalism, deliberately destroyed by people. Some villagers opened the door to the nest section and turned it into a barn, put their cows in the nest, and demolished the dovecote bush to do this. Most of the destroyed bastions created rubble filling in the nest part, and approximately 65 pigeon-holes are in this form and 49 of them require major repairs.

Table 5. Some examples of distortions (Albayrak,2021)	
	
Collapses on Tower Walls (57 units)	Discharge in Joints (44 units)
	
Color Change in Material (140 units)	Breakage and Loss in Stone Material (130 units)
	
Biodegradations (78 units)	Wrong Repairs and Interventions (25 units)
	
Rubble Fill (22 units)	

Table 6: Pigeonry no. 141 Deterioration examples







4. EVALUATION

Gesi dovecotes differ from other bird houses with their towers, nest sections, and alignment in harmony with the topography. Since it would be very difficult to measure these unique structures manually, the laser method was preferred. By combining all the point data of the structures obtained by data acquisition with a laser scanning device and scanning of the emerging point cloud, the dovecote towers and nests were revealed. All parameters that could be overlooked in the documentation to be made with manual measurements and photographs in the field have been eliminated by laser scanning. For example, since the spatial measurement of the slots that can be entered, depending on the special geometry, is made by laser scanning, the accuracy has increased. Again, measurement errors that may arise in dovecote towers exceeding human height are disabled.

As a result of the preparation of the survey, restoration and restitution projects of Gesi dovecotes with laser scanning technology, the following technical achievements have been achieved;

- A rich archive has been gained as a result of visualization studies for the protection of pigeon houses with the details of the current situation of the cultural heritage, damage assessment and evaluation.
- Thanks to the 3D point cloud data obtained with the laser scanning device, an infinite number of drawable models were obtained from every corner of the dovecotes and from different viewpoints by taking the plans, sections and facades of the dovecotes from any desired elevation.
- The time spent in repetitive measurements and registration processes made with traditional methods is not lost in laser measurements. Compared to traditional methods, laser measurements provided fast results in terms of work performance.
- Thanks to the laser scanning technology, it can work in dark environments such as the slot where daylight is low, just like in daylight. Thanks to this feature of the machine, measurements can be made without the need for artificial lighting.
- The accuracy of the data obtained with the point cloud method scans obtained as a result of laser scanning was determined as 99.9% (+- 2 mm) by the digital measurement team.
- Obtained 3D point cloud, orthophoto images, drawn plans, sections and facades can be easily archived in computer environment. Thus, thanks to the practicality of filing, space saving was achieved in offices from volumetric areas.
- Transfer and sharing of digitally archived documents in the office e-mail environment is a faster and more practical way. Thus, the processes gained in the fields of workflow and project management shorten the delivery period in the conclusion of the project and make a positive contribution in terms of project management.
- By classifying and transferring the structural findings obtained during the preparation of the survey and restoration project to digital media, the technical findings of the past periods in the field of construction technologies were brought to light.
- Since there is no contact with the objects to be scanned during the laser scanning phase, the historical texture is not damaged.

5. CONCLUSION

Preserving cultural heritage is an imperative task for all civilizations in the world. In order to keep the traces of civilizations alive, it is extremely necessary to transfer historical and cultural artifacts from generation to generation. Terrestrial laser scanning method has become the reason of choice for many disciplines with its potential to obtain cost-effective, high-accuracy data in a short time (Okuyucu & Çoban, 2019). Laser scanners, which ensure that architectural documentation works are carried out in a healthy way and in accordance with the determined standards, have become preferred by users in our country and in the world.

Different from traditional methods, terrestrial laser scanning method was preferred for the preparation of survey projects of Gesi dovecotes. Terrestrial scanning device has replaced traditional measurement methods with the rapidly developing technology. The laser scanning method has advantages over traditional methods in terms of speed, workflow and workforce. Using a laser scanner for accurate measurement allows accurate preparation of survey projects. By using local laser scanning technologies, thousands of points reflecting the object or object surface are obtained. With the help of these points, realistic 3D models are obtained. According to the models created, area, volume and surface dimensions can be reached according to the size information of the object or structure. 3D point cloud data about the plan scheme, sections and facades of Gesi dovecotes, which are of historical importance, were obtained by using Faro Focus 3d laser scanning device. By installing devices in 815 different stations in the building area, the scans of the structure were made in 32 days and a point cloud was obtained. For each of the 147 dovecotes, the plan scheme of the towers and the plan of the 20 slots that can be entered were measured using the terrestrial laser method. For each of the 147 dovecotes, at least 2 cross-sections and four frontal views were produced. Numerical survey with the help of 3D point cloud data obtained by using Focus 3d laser scanning device.

With the help of 3D point cloud data obtained by using Focus 3d laser scanning device, it was converted into numerical survey measurements and survey drawings were created in the computer environment. By using this method, since the scans performed can be combined in the computer environment, images giving information about the whole building can be obtained. Removing the survey of Gesi dovecotes by laser scanning method, apart from traditional methods, had a positive effect on the study in terms of time, quality and accuracy. The use of laser scanning technology has provided the opportunity to reach digital surveys and visual documents about the entire dovecote. In this study, the usability of terrestrial laser scanning Focus 3d laser scanning and Scene 5.4 software in architectural documentation studies was investigated. It was concluded that terrestrial laser scanning is a suitable method for documenting the heritage structure. Thanks to the CAD software developed in recent years, 2D representation of historical and cultural heritage and 3D modeling studies have accelerated the design processes.

Technical drawings, analyzes and simulations can be obtained with the CAD software, which includes many modules that allow 2D and 3D work. Thanks to the point cloud function that comes with the AutoCAD software used within the scope of the study, 3D visualization can be made by capturing the points in the point cloud. It is extremely important that the software allows 3D drawing over the point cloud. Autodesk Revit program is as useful as AutoCad in converting a 3D point cloud into a survey project.

In our country, 3D modeling studies are preferred in documenting our historical and cultural heritage values. With the constantly developing CAD software possibilities, it will be easier to work on 3D point cloud data and the details of complex objects such as dovecotes will be drawn more easily. In this way, studies on point clouds can provide different dimensions and new gains to heritage documentation studies.

In the study, intervention plans, damage assessment sheets, survey, restitution plans, restoration sheets were obtained for 147 pigeonries. When digital data acquisition is compared with traditional method data collection, it is observed that the process is shortened and there is a deviation close to zero with 99% accuracy. In line with these results, it is a study that reveals the priority of the laser measurement technique as the reason for preference and the validity of the preference, especially for the example of preparing the survey of Gesi pigeonries with terrestrial laser scanning method.

When the data obtained with laser scanning technology is compared with traditional methods, it has been seen that the Laser scanning method is more advantageous in terms of process / performance / accuracy and cost analysis.

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Author contributions

Mahmut ALBAYRAK: Case Study Survey, Software, Data curation, Writing-Original, Field Examinations
Gonca BÜYÜKMIHCI: Conceptualization, Methodology, Writing-Reviewing and Editing, Investigation, References Provide.

Conflicts of interest

The authors declare no conflicts of interest.

Statement of Research and Publication Ethics

The authors declare that this study complies with Research and Publication Ethics

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Documentation Methods from Tradition to the Present: Case Study Cappadocia

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Laser Scanning
Photogrammetry

ABSTRACT

In addition to its natural geomorphological formations, Cappadocia is one of the rare regions of our country that is worth visiting with its unique topography and the traces of the different civilizations that lived here. The influence of geography on nature and people in the historical development process can be traced through the craftsmanship of tufa and rock as building materials by the various cultures and settlements founded and developed in Cappadocia Region. In early Christianity, the Byzantine Period, and the Middle Ages, the cultures of the region built underground cities, religious buildings, monasteries and churches, residences and farms, workshops, necropolises, and rock tombs. When Cappadocia is mentioned today, the first thing that comes to mind is rock architecture in this form. It is not easy to obtain realistic data by measuring these spaces, which are usually carved into a monolithic mass of rock, using traditional methods, which is a prerequisite for preserving this type of rock architecture that has become an essential part of our Cultural heritage. However, software developed in digital environments with evolving technology saves time and money regarding accuracy and realism. It offers researchers practical advantages in terms of usability, archiving, and rapid remote access to data. The photogrammetry-based Agisoft -Metashape program described here provides a foundation for future studies or applications by combining data obtained by laser scanning on the same platform with interior and exterior measurements of the building and its surroundings, making the necessary preparations for analytical surveying, and archiving them on platforms with multiple access.

1. INTRODUCTION

The region of Cappadocia, with its historical geography and various material and cultural layers, has a special significance in its cultural and historical development process. This series of partially hidden settlements and spaces inscribed in the topography carry cultural heritage values that create significant awareness with their different architectures, aesthetic expressions, and various techniques and materials they use. Accurate, realistic documentation of these structures, which are rapidly being worn away by nature, man, and time and have often lost their integrity, is crucial for future generations and today as a basis for interventions to be proposed for conservation (Figure 1).

Figure 1. Basil the Great Church, Mustafapaşa 2017

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Obtaining an up-to-date and detailed data set using traditional measurement and documentation methods that document every point of the building and its immediate surroundings are often incomplete because it involves a laborious process. Documentation studies conducted in the past mostly remained at the level of sketches providing general information about buildings and spaces.

With the rapid advancement of technology, documentation methods and techniques have evolved from simple measurement techniques, which have significantly changed over time, to a multi-dimensional and multi-dimensional documentation system created using non-contact digital technologies.

The use of methods and techniques such as UAV, GNSS, Photogrammetry, Laser Scanning, Lidar Scanning, and RTI to reveal surface details is vital for the accuracy of the documentation (Akçay 2016:1-16; Yılmaz et al., 2008). Holistic and detailed documentation of historical monuments also serves as a basis for conservation action plans. This is because the *Historic Building Information Model* (HBIM) forms the basis for both structural and conservation analyzes (Dore et al., 2015: 351-357; Yakar et al., 2010).

In this regard, the study's challenge is the concept of protection of historic buildings, which have an extremely important place in the extensive history and diverse architecture of the Cappadocia Region. Examples will be used to discuss traditional documentation methods from the past about the historical structures in question and the application practices of the new methods and techniques used in current documentation systems in light of today's technologies.

2. HISTORICAL GEOGRAPHY and ARCHITECTURE of the REGION

The region, whose geological date of origin dates back to 13 million years ago (Neogene Period), received its characteristic feature through volcanic movements and erosion (Tuncel, 1996:14). Erciyes Mountain (3916m) in Kayseri, Hasan Mountain (3253m) in Aksaray, and Melendiz Mountain (2963m), formed 60 million years ago near Niğde, began their volcanic activities in the 10th century. The lava ejected by the volcanoes, which continued its activity throughout history, caused the volcanic cover to spread in the land to the north, forming a very resistant rock layer of basalt and volcanic ash (Esin, 2000: 80-83). The climate, winds, steppe surfaces, lithological features of the rocks, and the Kızlırmak, Melendiz, and Mavlucan river beds, as well as the tributaries feeding these rivers, provide the geological formation of the Region (Ötüken 1987:7).

Beginning in the Paleolithic Age, Cappadocia became a popular destination for human societies, which later formed towns belonging to various civilizations and cultures (Figure 2). Çatalhöyük, one of the earliest and well known settlements in Anatolia, and Aşıklıhöyük are located in this region.

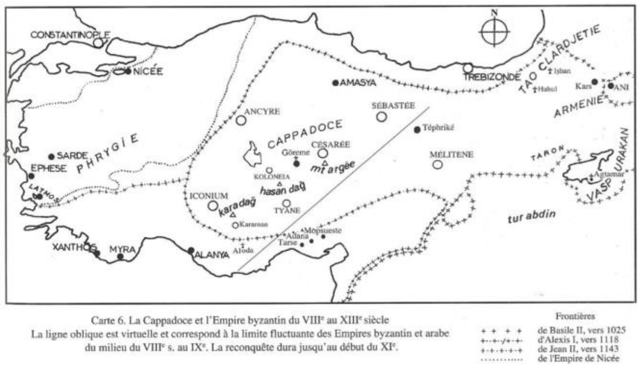

Figure 2. Cappadocia Region Map (Thierry 2002:75)

The word Cappadocia appears for the first time in Herodotus's work entitled '*History*.' The Persians gave the region a name that is the Hellenized form of "Katpatuka," which commonly held to mean "land of beautiful horses" (Hild and Restle 1981:63; Ötüken 1987:8; Kostof 1989:5). According to Strabon, one of antiquity's most prominent geographers, the Cappadocia Region's borders include the Taurus Mountains in the south, Aksaray in the West, Malatya in the east, and the Eastern Black Sea region in the North (Strabon 2012).

The oldest known written source about Cappadocia is a Hittite text from 2300 BC (Esin, 2000:65; Thierry, 2002:19; Ötüken 1987:8). During the Hittites period, commercial cities such as Kültepe (Karum/Kaneş) were located in the region, especially on the Mesopotamian trade route.

After the collapse of the Hittite Empire in 1200 BC, the Cimmerians (c. 700-650 BC), the Medes (c. 585 BC), and the Persians (c. 560-333 BC) continued to rule Cappadocia (Rodley 1985:5; Ötüken 1987:8; Thierry 2002:19).

The Cappadocia Region, which remained within the borders of the Roman Empire after the Persian domination, was accepted as a Roman province and Mazaka (Caisareia) city became the capital of the province (Hild and Restle 1981:64-65; Strabon 2000:15-19). The region, which was later included in the Pontos Region, was divided into second and third administrative units (Hild and Restle 1981:44; Thierry 2002:11-19) and became a part of the Eastern Roman Empire (Byzantine Empire) in 330 AD with the division of the Roman Empire into two (Hild and Restle 1981:70-84).

During the reign of different civilizations in Anatolia, a bridge between East and West in ancient times, many trades and migration routes passed through Cappadocia, and traces of different distant cultures were carried to these places. The geographical boundaries of the Cappadocia Region, one of the largest states on the Asian continent in Roman and Byzantine times, have changed several times over the centuries. It extended to the Salt Lake in the West, the Kızılırmak and the North Anatolian Mountains in the north, the Euphrates River in the east, and the Taurus Mountains in the south. Today it includes the east of Ankara, the north of Adana, the south of Yozgat and Sivas, and the cities of Kırşehir, Nevşehir, Aksaray, Niğde, Kayseri and Malatya (Hild and Restle 1981:42-48; Yakar & Yılmaz, 2008).

In the early years of Christianity, Christians prayed secretly in the caves of the Cappadocia Region.

Cappadocians used the rock carving technique to construct houses, temples, animal shelters, storage rooms, and burial structures in the existing topography. With the spread of Christianity in the region, they added to these structures churches, monasteries, and lavas for religious purposes (Rodley 1985:237).

The Region of Cappadocia, under the influence of monasticism, became one of the most critical cross centers of the Orthodox sect of Christianity in 300 AD. The clergy withdrew from the people and often chose high, rocky areas far from the city to be closer to God. The Cappadocia Region has been a region where different communities lived throughout history. Its topographical features were suitable for secret organizations and hiding places and created easy places to live. Göreme, Ürgüp, Çavuşin, Zelve, Ihlara, and the Soğanlı Valley are other areas where religious places and monastic churches are concentrated (Thierry 1971:129-171).

From the first half of the 7th century AD, Arab raids interrupted Byzantine rule (Kostof 1989:25), and artistic activities declined with iconoclasm. With the arrival of the Turks in Anatolia after 1071, a period of rapid change began for the region (Haldon, 2003:34). It is said that with the Seljuk religious and administrative policy, the Christian community continued its worship, but the monasteries and churches lost their former vitality (Ötüken 1987:5). The decline of social and political unity in the region led to the migration of the Christian community from the region and the abandonment of settlements and land (Vryonis 1971:148; Orhan & Yakar, 2016). In the Seljuk and then Ottoman periods, the sedentary culture, art, and architecture were continued using traditional techniques and materials.

Nowadays, the geographical boundaries are defined as "Cappadocia region" based on morphological characteristics by giving the coordinates of the area within the boundaries of Nevşehir province and Soğanlı valley within the boundaries of Kayseri province under the name "Priority Region in Touristic Development" (Özata 2015:5).

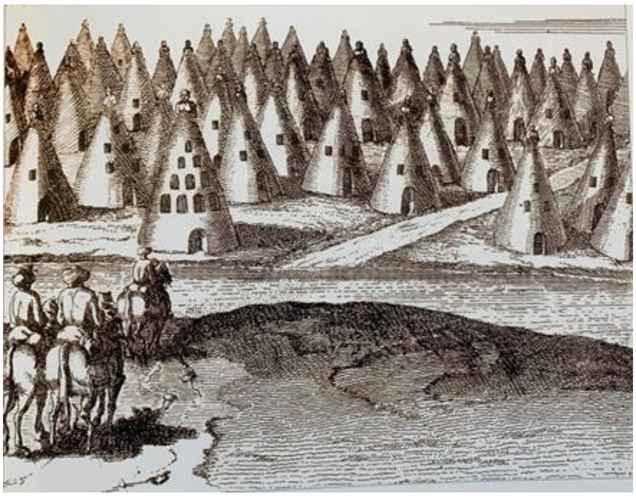

Figure 3. Paul Lucas, Cappadocia Stone Print Image (Fırat 1998:485)

The first scientific research in the region, which attracted attention in the West, was carried out by European researchers at the beginning of the 19th century. These early studies mainly concerned the architectural and art-historical evaluation of rock-hewn spaces, monasteries, and churches. The region, which attracted much attention, later attracted a growing number of explorers and travelers. In these first documentations of Cappadocia, drawings, charcoal drawings, simple sketches, and maps were used instead of photographs (Figure 3). With the development of photographic technology, attempts have been made to document the murals inside the churches that reveal the history and significance of the building.

2.1. The Architecture of the Region:

In the Cappadocia Region, the surface forms created by cuts in the valley slopes or monolithic rock masses in harmony with the topographic structure of the settlement have strongly influenced the region's architecture.

Many religious complexes, monasteries, and the structures that supply them were built in Cappadocia, which became an important cross center after the early Christian period. In addition to the churches, residential areas were created with many premises such as dining halls, kitchen halls, workshops, storerooms, and lavra.

Building complexes whose outer surface is the continuation of the natural topographical structure but whose interior is chiseled into space and designed with many units are considered religious architecture, especially the architecture of churches, plan typologies and reflections of Byzantine Period architectural styles. In general, in Cappadocia, the simple single-nave churches with the basilical plan with three naves, the central vaulted, closed, or open churches with the cruciform plan, more common in the countryside, were popular (Soykan 2019). There are two examples, such as the Keşlik Monastery Church or the Saklı Church, which were built by imitating the capital church architectures and combined with traditional materials and techniques as far as the topography allowed (Soybaş 2019; Ertürk 2020). Unexpected changes in materials and damage that occurred during the construction phase led to changes in the building's plan typologies and architectures. The damages or section losses that occurred during the period of use were tried to be repaired by procedures such as filling the wall with the masonry. In case of major destruction, the building was abandoned, and a new one was hewn in a nearby rock mass and attempted to be excavated.

The volume of the spaces created by carving into the existing rock mass was first determined with the help of an auxiliary line, and then, starting from this line, work was usually begun inward. The direction was sometimes intentionally changed by considering the formation of the rock structure, existing cracks, and soft layers. The heights of the spaces are generally adapted to the imitated architectural style, the side spaces and additional spaces are simpler, right angles and corners are bypassed.

It is possible to see the hand and arm movements of the masters and the traces of the tools they used in these places, most of which are believed to have been created by local masters. Since the rock material in the region is a type of ignimbrite, which is easy to work, the spaces could be easily built using the technique of carving and digging. Insufficient wall and floor thicknesses of the spaces created by the quarrying of tuffs, whose structural features work under pressure, and the large openings of spaces such as churches cause fractures and cracks in the tuffs. These structures and spaces, which have survived to the present day, are no longer used, and the architectural integrity of most of them has been damaged, and they have turned into ruins, destroyed mainly due to their exposed parts.

While some of these structures and spaces carved into the rock, distributed on Cappadocia region and bearing the traces of the past, are used today with similar functions, some have acquired new ones. While some are warehouses affiliated with legal entities and the private sector, some are included in units affiliated with the hotel and tourism sector. Some of the mentioned structures have been put under protection by including them in public institutions and ensuring their participation in daily life with new functions such as open-air museums and museums. However, a large part of our cultural heritage on this subject, especially in rural areas, has unfortunately been abandoned to its fate.

3. CURRENT DOCUMENTATION METHODS

Until the recent past, measurements and drawings of architectural documentation, plans, sections, and views were made and transferred by hand using simple techniques, instruments such as measuring devices, plumb bobs, spirit levels, and levels. However, it is challenging to document the real/exact dimensions and nature of the spaces created during rock carving and determine the height in places where transport is impossible and the depth and planning directions in the spaces within the rock. However, heights, elevations, depths, lengths, and diagonals measured by traditional methods and measurement techniques allow a general sketch to be drawn without measuring every point of space (Figures 4, 5). Considering the damages and losses of the documented building, it becomes more challenging to make accurate and real documentation and to measure and document the buildings and places located in difficult areas and heights, together with their immediate surroundings.

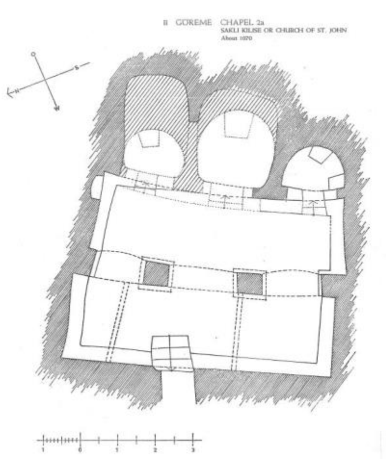

Figure 4. The Hidden Church (Restle 1967)

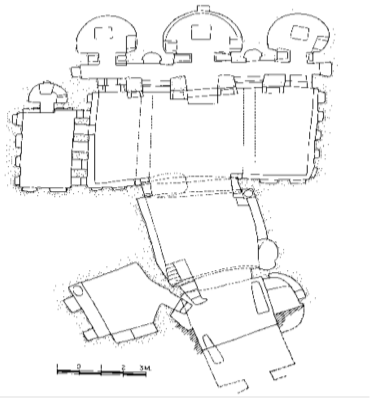

Figure 5. Buckle Church Plan Drawing (Epstein 1986)

In parallel with today's rapidly advancing technologies, systems and techniques have evolved, tools and equipment have been updated and modernized, and documentation methods used in many different fields and disciplines have begun to be cross-applied. Nowadays, digital captures that can be made with the technique of aerial remote sensing, photographing and scanning with drones and lidar, scanning tools that can transmit any point of the interior of the near environment and spaces, laser, for example, scanning with Faro, photogrammetric images allow to obtain more detailed and comparable data. In addition, ground scans with geo-radar or electrodes provide access to invisible data underground.

In addition, thermal imaging cameras that allow to see the destruction of the building and experiments on materials and strengths in the laboratory environment support this documentation and go into detail.

Documentation, which is a prerequisite for the protection of these sites, which are essential parts of our cultural heritage, and for subsequent preservation decisions, provides access to analytical survey data such as damage conditions, degrees, types, materials, and techniques, in addition to surveying the building, making the documentation truthful and accurate. Thus, due to the investigations in question, proposals can be made to restore the building, such as protection, consolidation, and conservation.

In the past, the measures and actions to protect these areas and places were limited to specific areas and structures. *Göreme Historical National Park and Cappadocia* were included in *The World Tangible Cultural Heritage List* in 1985 because of the need to preserve their natural topographical features and esthetic significance and their values as examples of interaction between interaction the environment and man. Residential areas such as Göreme, Paşabağları, Zelve, Ihlara, and Gümüşler Monastery are now partially protected by being converted into open-air museums.

Today, with communication and technology development, document integrity can be achieved on a common platform by combining them through intermediate programs from different areas. UAV/drone shooting parallel to the field or slope at a certain distance from the air, coordinate measurements made by satellite remote sensing method, mobile lidar scans just used with laser scanning inside and outside the building at close range, which is mainly useful for detailed documentation based on small structures and objects, can be converted into 3D images by analyzing mobile lidar scans, which can be used as a basis for architectural projects in the computer environment.

3.1. UAV/Drone Shooting and Photogrammetric Studies

Studies using UAVs and unmanned aerial vehicles are conducted in the digital environment, where these data are processed after the outdoor shots are taken in the area where the structure is located. For outdoor shootings to be made with the remote sensing method, specific permits and the training and certification of the person who will be flying must be separately notified to particular agencies, and a permit obtained. The timing of the flight, weather conditions, light distribution, and quantity all affect the quality of the shot (Şasi 2020:8).

Exterior shots should be planned to capture the settlement and the immediate region where the building is located. Problems may arise in documenting the pure structure, project design deliverables such as the site plan and silhouettes.

The study begins by flying over a specific route and altitude above at least five fixed control points placed here in the building and its immediate surroundings after establishing the boundaries of the area to be documented. GPRS/Cors primarily determine the coordinates of the control points and depending on the size of the area determined from a certain height distance and the desired clarity, photos can be taken, and measurements are taken as often and repeatedly as desired. The photos can be taken at a specific frequency so that they overlap in the desired rhythm. With each image taken, the distance traveled, and the GPRS coordinates of the area covered are also determined and transmitted (Şasi 2020:8). Additional programs that support shooting, such as DJI GS Pro and Map Pilot Pro, may also manage the area shots and the quality of the work. For example, 466 photographs were taken in an area of about 7 hectares in Göreme Saklı Church, Cappadocia, where this study was conducted, at an altitude of about 80m, with a flight of 2349m (Figure 6).

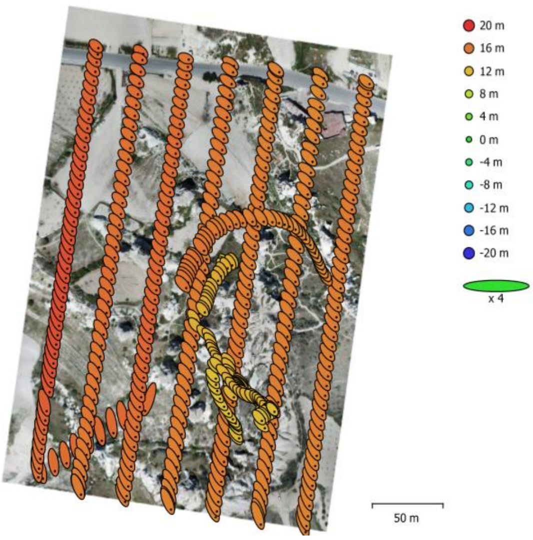

Figure 6. Camera Locations and Error Estimates (Ertürk & Kaderli 2020)

To produce a site plan, the photographs and coordinate data were analyzed in the computer using Agisoft-Metashape (software that generates 3D spatial data for photo scan digital images) (www.agisoft.com) and transformed into a three-dimensional DEM map using point cloud data. During this process, sensitive GNSS data received from Ground Control Points (GPC) placed in the surveyed area are also transmitted to the software and can be combined with geographic information systems and placed on the map in accordance with the country coordinates.

Elevation curves can be added to these documentations created from the outside of the building and its surroundings using the point cloud or the map DEM (Digital Elevation Model), and the desired cross-sections between points can be created (Figure 7).

Figure 7. Saklı Church, Section (Altın Oran 2020, Saklı Kilise archive)

In 7 steps, the program Agisoft- Metashape can transform data into 3D spaces in various representations and 3D modeling in volumes. Interconnected commands and intermediate transformations such as Dense Cloud, Mesh, Texture, Tiled Model, DEM, and Orthomosaic are possible with Align Photos (Figure 8).

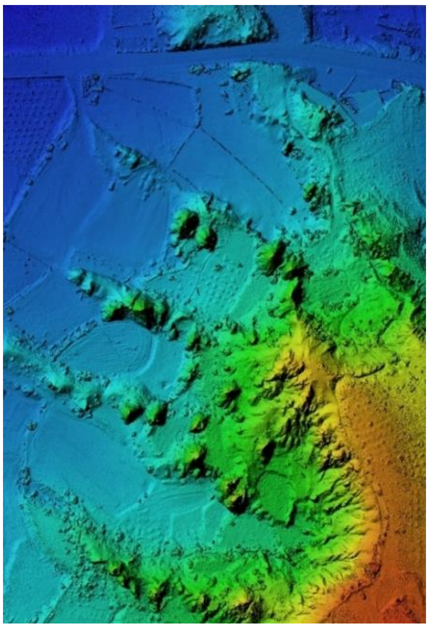

Figure 8. Hidden Church, DEM Map (Ertürk 2020)

For a certain repetition and registration, for example, at least 60%, for an accurate result, each photo is combined with the previous image and the next photo to 80% and converted into a point cloud (dense cloud) together with the coordinates and shooting points from the numerical data, and the triangulation method is used to create the surface, process the solid model (mesh) and then the photoreal mesh to create the 3D model (Akçay & Gürel 2018:1-18) (Figure 9). The scanned area, valley, monolith mass, and entire outer volume of the structure can be created in real dimensions without escaping into a 3D perspective if the fixed points and coordinates (guide and ground control points) taken at the start of the program are transferred to the program and matched with individual photographs. With the export command, this collected data can be transferred to the dxf, dwg-extension-Autocad environment at the appropriate scale, and a base for survey drawings and damage assessment studies can be created.

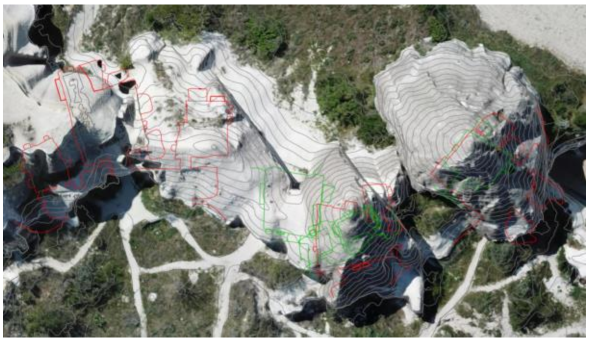

Figure 9. Saklı Church Elevation Curves (Ertürk 2020)

3.1.3. Laser Scanning

In recent years, laser scanning technology has evolved and is now being used to document and survey complex structures with difficult shapes and areas requiring detail (Reshetyuk, 2006; Karşıdağ & Alkan 2012; Yaman & Kurt 2019:6). 3D models of the scanned structure can be obtained with the necessary software without physical contact with the structure and with the desired precision (Kaya, et al., 2020:58). Although terrestrial scanning technologies are used in many different fields, they are widely applied to cultural heritage recording (Lichti & Gordon 2004; Fabris et al., 2009; Yunus Kaya et al., 2020:61; Çelik et al., 2020).

Figure 10. Saklı Church (Ertürk 2020)

In the documentation studies from the ground, the immediate surroundings and the internal volume of the building can be scanned with a laser scanner with HDR photo function, and a large number of point clouds can be converted into models with laser programs such as Scene (Faro brand laser scanning program), which obtain the real 3D values (Figure 10). The point data generated by recycling the rays that can be reflected from the laser device to any point of the building can be converted into a point cloud by the program. Depending on the laser scanner used, the settings for sharpness and resolution may vary. With the camera, which is usually integrated in the devices, photos are taken in a complete 360° circumference and transferred to the point cloud, and textures and colors are processed. In this study, for size and scale control, it is important to determine the coordinates of the reference and guide control points using GNSS.

After the ±0.00 point of the building or terrain has been determined, the clip boxes of the desired sections can be opened and plan, section, view orthophotos can be taken (Figure 9). The orthophotos can be transferred to scale into the Autocad program and placed. In this way, a basis can be created for the necessary plan, section and view drawings for the survey (Figure 11).

Figure 11. Saklı Church, Sectional Perspective (Ertürk 2020)

Figure 12. Keşlik Monastery, Archangelos Church, Sectional Perspective (Soybaş 2019)

A software like Scene2go can also be used to easily access large file sizes in the scaled documentation portion of the data. Known documents, 3D models stored in the computer environment, and various databases, photographs, jeans, and various measurements can be retrieved by back-reference as needed (Figure 13, 15).

Figure 13; 14. Saklı Church, Narthex, Scane2Go Program (Altın Oran 2020, Saklı Kilise archive)

3.1.4. Mobile - Lidar Scanning (Light Detection and Ranging or Laser Imaging Detection and Ranging)

One of the latest current applications in documentation today is mobile tablet-Lidars-. At the same time, it can scan the desired area or structure by hand using the camera and laser scan on the mobile lidar tablet, which also has the smartphone option - Lidar Scan - with different capacities and processing speeds, and then create a 3D model by processing this data. Cameras with a fast focus can also detect depth. These limited capacity devices are more successful at scanning small objects such as chairs, doors, alcoves, tables, or a single room scale but have difficulty processing and recording data as area and volume increase. To use these tablet features, you need to install additional programs such as 3D Scanner, Matterport, Polycam. With its easy-to-carry features on a mobile device, the digital documentation technique and method, which is also used in areas such as modeling small objects in various areas, interior architecture, decoration, and various digital games, is very practical and fast. It can precisely work in different topographies, geographies, hard-to-reach places, small volumes, and areas where other instruments have difficulty entering and shooting.

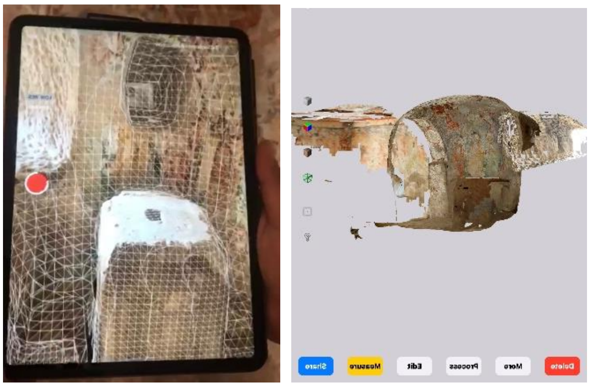

Figure 15. 3D Scanner, Lidar Scan, Mesh
Figure 16. Scanner, Lidar Scan, Mesh Textured

The lidar scanner operates at the photon level and nanosecond speeds. It can measure the distance of objects in the environment up to 5m and can be used indoors and outdoors. Depth software frameworks combine depth information measured by the lidar scanner with data from cameras and motion sensors and can be augmented by computer vision technologies on the bionic chip to provide a more detailed understanding of the landscape, structure, or object. Because the close integration of all of these factors can provide a variety of AR experiences (Apple 2021). It is believed that in the future, devices will be developed that can succeed up to a certain distance to increase their capacity and clarity.

The 3D Scanner program, which also takes photos with laser scanning, can create real models by converting the scan to triangular surfaces with the Mesh command in Agissoft (Figure 15), converting it to solid, and then dressing it with textured texture (Figure 16). 3D models, like other programs, can be perceived in different planar dimensions and can provide sections from anywhere (Figure 16). The created models can be shared with various program extensions such as OBJ, GLFT, GLB, STL, FBX. As with other laser scans, time of day and light settings are essential for getting the best possible digital documentation efficiency. However, some programs offer different scanning degrees (3D scanners).

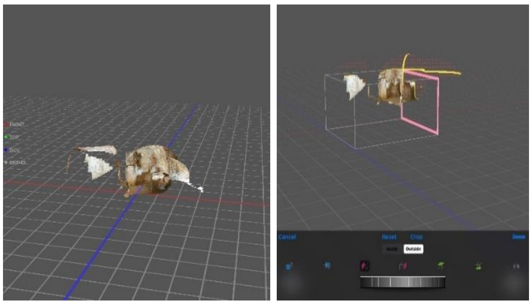

Figure 15. 3D Scanner, Lidar, 3D Scanner Program, Edit, Planar 3D Image
Figure 16. 3D Scanner, Lidar, 3D Scanner Program, Edit, Crop With Box, Sectioning

4. GENERAL ASSESSMENT

Archaeological material, cultural remains, and architectural structures that document our attachment to the past through different cultural layers in the process of historical development shed light on our history and allow us to understand the lives and experiences of the past, have value as a cultural heritage that should be protected at the primary level. The transfer of these values into the future, objectively and as information, and their protection is only possible with detailed and realistic documentation methods.

In ancient and late antiquity, settlements, structures, and places in the Cappadocia region were formed by man-made tufa processing into the bedrock, using the region's typical construction style. Murals, especially on religious buildings adorned with various decorations, are designed as topography permits. Some of these structures and locations have been converted to other uses, such as hotels, warehouses, barns, open-air museums, or abandoned by the private sector, legal entities, and public institutions after losing their original use over time. Time, natural climatic changes, processes of destruction by the material itself, section losses have been and are being destroyed under the name of the human factor (vandalism) and tourism, with the increasing interest in the region in recent times. Those who have managed to be in a better condition today are, for the same reasons, waiting defenselessly for the damage that may occur soon.

Instead of documentation studies that were done in the past using traditional methods, today, measurements, evidence, and documentation are done using various methods and techniques, new technologies, and rapidly developing technology. Through the joint use of different acquisition, scanning, and recording devices (UAV, Laser Scanning, Lidar Scanning), more comprehensive holistic and realistic models are created, and these models are converted into the desired program formats.

Combined with UAV and drone imagery, indoor and outdoor terrestrial laser imagery used primarily for site plan-based outdoor coverage, and mobile lidar scanning that has been successful in hard-to-reach areas, this can yield highly detailed, easily and quickly access data that can be used for conservation projects, analytical studies, and other analyses.

Moreover, these documentations can provide evaluations not only for the investigation carried out for protection, the determination of the current situation, but also for the convenience they can provide in restoration, decisions about conservation interventions, the effects of the destruction of the structure, the damage simulations that can be predicted for the possible future, and the structural changes. It can also be used for new designs, such as new building additions, re-functioning, shelter roofs.

Using multiple documentation techniques and methods (cross/interdisciplinary) in documentation studies conducted under challenging areas and topographies such as Cappadocia and in areas lacking clear architectural formation results in a holistic, real-world data system. 3D models that can be created outside of 2 dimensions provide all the architectural data associated with the structure and provide convenience in archiving and storing these documents by allowing quick remote access, conservation processes, structural analysis, and restoration applications where theory is put into practice.

Author contributions

Conceptualization, Methodology, Writing-Reviewing, Field Survey

Conflicts of interest

The authors declare no conflicts of interest.

Statement of Research and Publication Ethics

The authors declare that this study complies with Research and Publication Ethics

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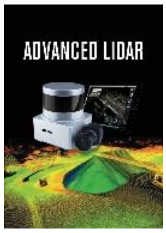

Lidar to HBIM for Analysis of Historical Buildings

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Keywords
Cultural Heritage
HBIM
Point Cloud
Lidar

ABSTRACT

The design, documentation and construction processes in Architecture, Engineering and Construction industries (AEC) have been undergoing major changes in recent years with Building Information Modeling (BIM). The use of BIM together with 3D laser scanning (LIDAR) technologies has brought great innovations by going beyond traditional methods in studies carried out in historical environments. With the developed of used technologies together with Heritage Building Information Modeling (HBIM), efforts documentation and rehabilitation of historical buildings have rapidly increased in the last ten years, especially in European countries. This article provides a framework for the implementation of LIDAR to HBIM related to heritage buildings in Turkey. An approach is carried out a process that is a workflow from document historic structures with 3D laser scanning and subsequently generation of a HBIM model. The process of producing an different detailed of HBIM models for provide the documentation and restoration needs of historical buildings from point clouds and processed point clouds for using different platforms was carried out as a case study.

1. INTRODUCTION

Along with technological developments, the using of tools such as 3D terrestrial laser scanning and photogrammetry, which are used for documentation, in construction processes has facilitated the applications and design processes. These tools, which acquire precious data with high accuracy, providing access to the detailed geometrical features of the structures, provide advantages over the repetitive steps of traditional methods in many ways such as time, total working time and quality (Rocha et al., 2020). 3D laser scanning (LIDAR) is a measurement technique that is suitable for documentation on complex and high-dimensional objects with various scales (Wang and Cho, 2015). Laser scanners, based on LiDAR technology, sends high-intensity laser beams to scanned objects and then calculates the coordinates of each point, which are the laser hits. High speed 3D point cloud models can be easily obtained with these technologies. Thus, it creates a high-density point cloud model of the scanned object (Marzouk et al., 2016; Yakar et al., 2010). Point cloud data represents the captured geometry of the entire building. Laser scanners capture and record information such as texture, surface color, as well as geometry of building. Laser scanner technology determines different types of principles and functions, and levels of accuracy and precision for different environments (Chiabrando et al., 2016). It can measure and recognize inaccessible areas. It can properly connect between indoor and outdoor. (Mol et al., 2020). The integration of laser scanning into the BIM workflow has brought innovation to all architecture and construction services, including existing building interventions (Quattrini et al., 2015). With the two platforms coming together, it provides facilities for obtaining important parameters in documentation, management process, error detection, intervention and repair options. After making intervention decisions on a historical building, many stakeholders are involved in that process. Thanks to the management process, monitoring, control of different disciplines and decisions on a single platform can be achieved by the effective use of BIM and LIDAR systems. Integration of the two systems would be very helpful for making intervention decisions as well as minimizing their errors. But this integration requires a challenging and qualitative works. Because it requires a disciplined fieldwork, qualified data combination, processing and then a comprehensive modeling process (Piderit et al., 2019; Alptekin et al., 2019). The study focuses on the combination of LIDAR-BIM, which includes these processes. As a case study, the process of digitally making HBIM models of a historical house is explained.

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2. METHOD

The combined use of LIDAR and BIM systems follows a reverse process in terms of construction techniques, unlike new buildings in historical buildings (Bruno and Roncella, 2018). Process; It consists of 4 different stages with LIDAR data. Point cloud processing, HBIM model and drawings obtained from the model; each stage is realized depending on the previous purpose (Figure 1). Before scanning, firstly, with observation-based examinations, all information about the architectural features of the building is obtained. In addition to observational studies, the details of the building are recorded by photographing (Figure 2).

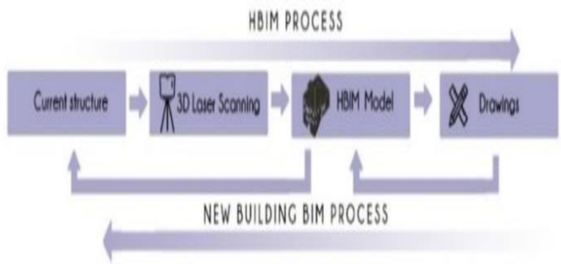

Figure 1. Working Process

Figure 2. 3D Laser scanner of historical house

2.1. Terrestrial Laser Scanner for case study

Horizontal and vertical measurements of the building were taken with Faro Laser Scanner, which can measure without reflector. Although the measurement consists of certain stages, primarily the determination of the places to position the Laser Scanner around the structure to be measured, that is, the polygon points are determined. These polygon points are connected to the first polygon point (P1) where the measurement will be made and the other polygon points. The numerical equivalents of the x, y, z values of the connected polygon points in the coordinate system are recorded by laser scanner. Thanks to the these polygon points all scanner positon were aligned. This method increased the quality of the alignment and error values were reduced.

2.2. HBIM (Heritage Building Information Modeling)

Building Information Modeling (BIM) is an integrated collaborative methodology for the design, manufacture, display and management of structures (Eastman, 2008). Nowadays, it is mainly used in new constructions and designs (Ma et al., 2016). Unlike current practices, Working with historical building much more difficult compere with modern structures thanks to the uniqueness of historical buildings, their non-standardity, the anomalies in the spatial features, the limitations in materials (Green and Dixon, 2016; Ulvi & Yakar, 2014; Alptekin et al., 2019). Historical Building Information Modeling (HBIM) is a system that all data could be storage in that platform and could be manage this data for analysis and management of historical buildings. HBIM could contain different data received from related engineering works. Thanks to the HBIM, decision related to historical building can be make base on overlapped knowledge. HBIM platform also allow user to manage point cloud data and to modeling of historical building using with it. Using of laser scanning data, which contains a large amount of knowledge far beyond three-dimensional representations, due to the differences and difficulties of buildings in terms of historical, cultural, physical and construction techniques. (Murphy et al., 2009; Gigliarelli et al., 2017). It could be said that high accuracy 3d documentation should be necessary for cultural heritage studies because historical building studies have some constraints and difficulties related to data collection and also geometries of historical buildings should represent existing shapes in project and decision making process (Tapponi et al., 2015; Yakar & Yılmaz, 2008). The combination of HBIM and Lidar could be provide complex knowledge to effective method for conservation of historical building. It could be said that knowledge base decisions could reduce historical building risk factor related to construction and conservation practice (Malinverni et al., 2019; Yılmaz et al., 2008) (Figure 3).

2.2. Case Study

Ermenek district of Karaman province in Turkey was chosen as study field where Ayfer Sönmez Historical House is located as a case studuy. Ermenek is located within the geographical structure of Southern Anatolia, surrounded by Antalya in the west, Konya in the north, Mersin in the east, and the Mediterranean Sea in the south (Figure 4). There are many architectural heritage buildings built in the first quarter of the 20th century in the historical town. Historical buildings in the region are preserved and used in this town and also surrounding settlements. In general in this region; It is observed that the houses are two-storey and made of stone and wooden materials. This historical building has dominat character and view in Ermenek urban townscape. Becasue of the house features and character conservation projects were prepared for prolong life of historical buildings and confortably using this building and update historcal building's phisical condition to current standarts especiallay related to it's energy performance (Figure 6-7).

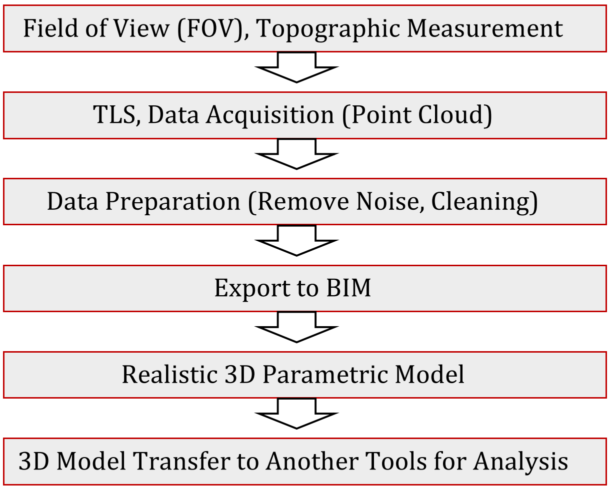

Figure 3. Workflow of point cloud to HIM steps


Figure 4. Ermenek location

(a) (b)

Figure 5. (a)- Case Study Traditional House
Figure 6. (b)Case Study Traditional House

3. DATA AQUSITION, POST PROCESSING and HBIM

Data acquired with Terrestrial Laser Scanner (TLS) (Faro S120 Laser Scanner) were transferred and aligned with Scene 5.0 software. All alignment, flittering, cleaning works carried out in Scene software. Autodesk Recap software also provide some opportinities related to post processing works. Sequential operations such as data processing, database formation, point cloud editing, file format editing were carried out in these software. After editing the scan data, the point cluster is exported to Revit software in RCP file extension (Figure 7-8).

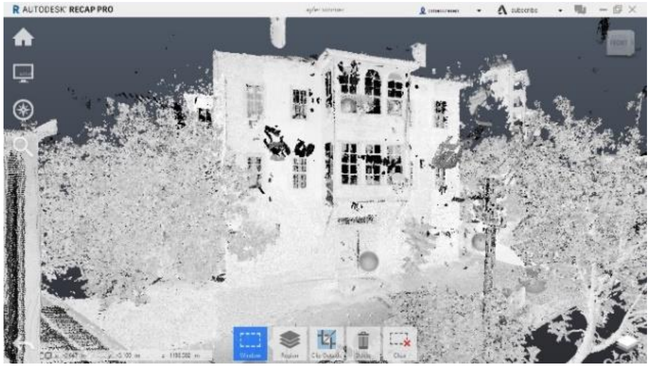
Figure 7. ReCap Pro point cloud post-processing

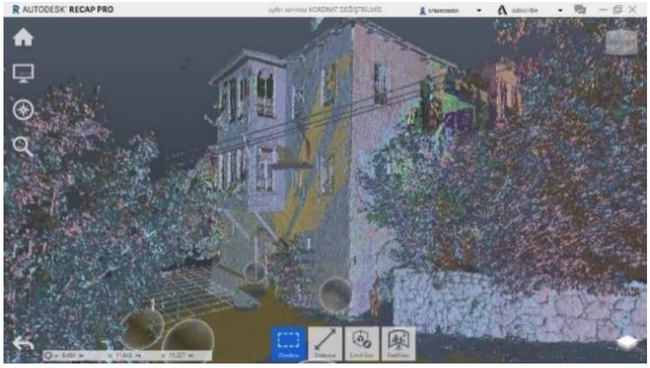
Figure 8. ReCap Pro point cloud post-processing

Before starting the modeling, some steps need to be done. The first is to get the coordinate of a point in the point cloud and to determine the coordinates of that point (preferably the ground) in the working interface in Revit. After the point set is transferred, it is moved to the determined point coordinates without changing its original coordinates. In this way, some problems that may arise in point cloud coordinates in Revit are solved beforehand. At the same time, this process ensures that when placing the point cloud, the building's ground level is automatically placed at level 0 in Revit. After that, the point cloud within the project is fixed. These operations prevent any change in position in case the point cloud is revised again. After the point cloud location is fixed, the model can be started to be created over the point cloud with Revit tools (Figure 9-10).

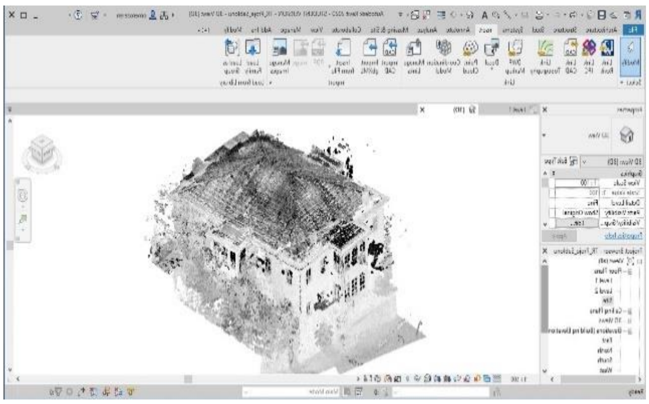
Figure 9. General view of point loud in Revit

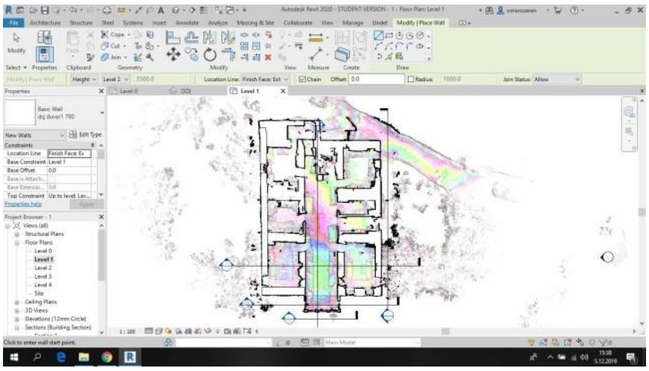

Figure 10. General plan section of point cloud data

One of the detail to be considered while creating a model is the wall types according to different thicknesses and geometric properties. It would be easy to classify and access different type of walls, if they are modelled according to their properties. HBIM platform provides detailed model according to aims of works. The model's level of detail (LOD) determines the quality of the resulting project. Therefore, attention should be paid to details while working. Photographs were taken during the fieldwork for support the model and special objects are produced. In this way, a more advanced model could be obtained (Figure 11-12).

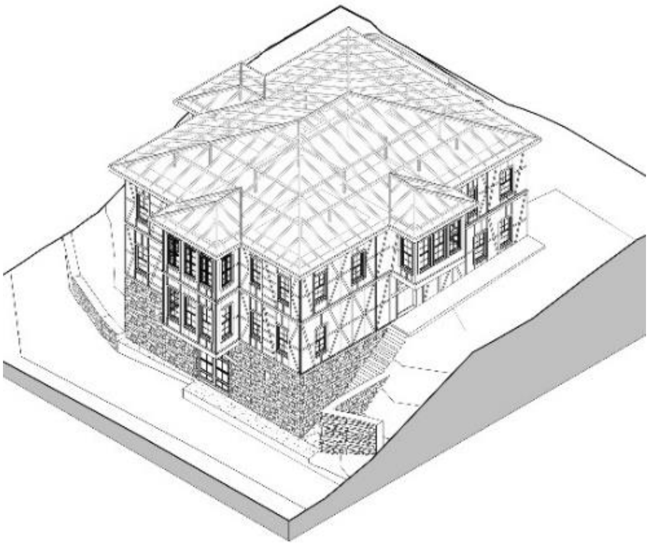

Figure 11. HBIM modeling

Figure 12. HBIM modeling LOD 350

Figure 13. Structural model in BIM Platform

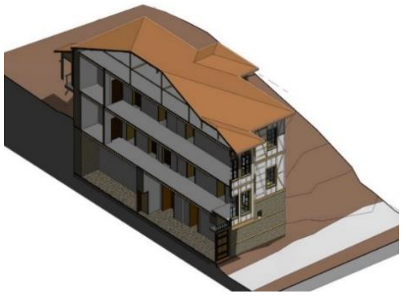

Figure 14. HBIM model section with LOD 350 detail

The final model could be used in different analyzes and simulations. The most important of these are related to the energy efficiency of the building. Using with these models, the amount of energy required and consumed by buildings can be calculated. Structural analysis can be made using these models with some plugin in HBIM platform. Different engineers can import these models into their own software. HBIM-based model can be used for analyzes such as disturbance analysis, mapping, etc. The main data source of all these analyzes is high-accuracy laser scanning data (Figure 13-14).

4. RESULTS

The use of LIDAR systems makes valuable contributions to architectural, construction, conservation, renovation decisions and processes. LIDAR and HBIM platforms could be operated and used in direct integration with modern documentation techniques. With this cooperation, qualified, fast and more accurate intervention decisions could be made. At the same time, using these two platforms together provides documentation of buildings with reduced errors. With the conveniences HBIM platform some works could be easy done such as high accuracy data collection, management of this data, detailed 3d models. Most of this works couldnot be done with tradational techniques. When using HBIM software, user ability is very important for quality model production. Use of laser scanning and HBIM model generation; data management requires architectural expertise as well as software skills to manage a point cloud. When LIDAR and HBIM are used efficiently in the field of cultural heritage, they make an important contribution to the production of the most appropriate solution in the design and using of cultural heritage.

Point Cloud data and HBIM platform create high-accuracy models for different analysis. Other engineers are provided to analyze with detailed data. Analyzes made with these data are easily used in many innovative computations for designer and restorer.

Author contributions

Ömer ÖZEREN**:** Case Study Survey, Software, Data curation, Writing-Original,
Mustafa KORUMAZ**:** Conceptualization, Methodology, Writing-Reviewing and Editing, Field Survey

Conflicts of interest

The authors declare no conflicts of interest.

Statement of Research and Publication Ethics

The authors declare that this study complies with Research and Publication Ethics

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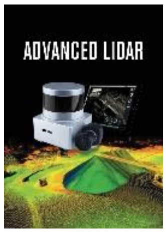

Terrestrial Laser Scanning with Potentials and Limitations for Archaeological Documentation: a Case Study of the Çatalhöyük

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Keywords
TLS
Archaeology
Documentation
Catalhoyuk

ABSTRACT

The evolution of digital technologies has impacted the documentation of cultural heritage. One of the steps that have passed considerable change is maybe the stage of data collection field. Today many different technological tools may be found at affordable prices. The suitable method for cultural heritage documentation should be chosen considering the needs of research, analysis and conservation. There is no definite way in order to determine which survey technique is the most suitable one in any situation. Digital photogrammetry, total station, GPS, texture mapping, laser scanning techniques are mostly preferable when high accuracy needed and can be supported by traditional tools like rectified photographs and stereophotogrammetry. In recent years, laser scanning shows great versatility for capturing any type of shape and speed of data acquisition. However in some cases, Terrestrial Laser Scanning (TLS) can have some limitations. In this study, Çatalhöyük archaeological area was documented with TLS and experiences were shared as potentials and limitations of TLS for archaeological documentation.

1. INTRODUCTION

In archaeology and cultural heritage, related projects there is often need for a rapid and accurate documentation of the objects. Since the process is dynamic, it requires fast and preferably non-immersive documentation techniques. Besides, the technique inevitably should be suited to cover the complete area (Sauerbier and Eisenbeiss, 2010). Even though fast, accurate, cheap modelling and visualization of archaeological areas is a demand, there are some justifications making this demand difficult. The first reason for this difficulty is directly related with the complexity and geometric and radiometric features of archaeological areas, while the second one is more related with its conceptual interpretation since it is a scientific document. These reasons make a need for new methods instead of traditional ones for archaeological documentation.

String grids and basic traditional methods may not provide accuracy standard which architects need in many situations. Simple survey of the site similarly can only provide a layout with a few accurate points connected with vectors, without any further information. These methods both need extra people working within archaeological site for a defined period of time, which increases the economic cost, as well as the possibility of accidental destruction of important findings. Additional security precautions should be taken in order to prevent any possible damage to the surveyor or archaeological remains (Ioannidis et al., 2000). Another used traditional techniques like tracing with wet paper and pencil/crayons, free-hand drawing, photography, plaster molding, latex and wax rubbing to record inscriptions or significant details on the surfaces may not reproduce the degree of detail and accuracy required by today's researchers and conservators (Diaz-Andreu et al., 2005). Besides it takes time to prepare it for drawing which could be only 2D.

In last decades, there has been an increasing demand in the digital documentation of archaeological sites and artefacts with development of new technologies. In this sense, three-dimensional photo-realistic models allow to document, manage and analyze

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the shape and dimension of the represented objects with a high degree of accuracy and resolution with the potential for recording.

Archaeological data is extremely complex from a geometric point of view and existing methods of 3D modelling lead to large simplifications. In addition, the data also should be easily scalable to support different levels of visualization quality. Detailed geometric information about archaeological sites can be obtained by using terrestrial laser scanning (TLS) methods as well as topographic surveying, photogrammetric techniques and Terrestrial Lidar Acquisitions (Apollonio et al., 2011; Brown et al., 2001; Lerma et al., 2010; Yilmaz et al., 2012; Yakar et al., 2010). These techniques made it possible to obtain a high level of detail and accuracy and result to be very effective, especially for small or medium-extension archaeological sites (up to tens of hectares).

According to the classification of metric survey techniques by English Heritage, direct and indirect techniques are mainly applied in cultural heritage documentation field (Heritage, 2011; Ulvi & Yakar, 2014; Yılmaz & Yakar, 2006)). Direct techniques includes hand measurement, levelling, total station and GPS while indirect techniques involves remote sensing, rectified photography, artefact scanner, close range photogrammetry, remote sensing, terrestrial laser scanning, airborne lidar and aerial photogrammetry. In most cases the combination of these technologies and related methodologies regarding their benefits may be the best solution depending on the final product since each of them has some limitations and advantages (Grussenmeyer et al., 2008; Patias, 2006; Alptekin et al., 2019).

As a direct technique, hand measurement can provide dimensions and positions of objects and scenes of a few meters, sketches in small size which is sometimes more impractical and not enough for larger objects. In this case, photogrammetry and terrestrial laser scanning could be more suitable by covering larger areas and enabling a large quantity of three-dimensional measurements to be collected. The studies have shown that photogrammetry has advantages for large amount of data, accurate data, possibility to texture in high resolution and detail, geo-reference data with stereo-viewing capability of the 3D data (Grussenmeyer et al., 2008, Patias, 2006). Similarly Terrestrial Laser Scanning technology has high performance in terms of data acquisition speed in different field of uses and has advantageous when used appropriately (Andrews et al., 2010).

In this project, archaeological area Çatalhöyük was surveyed with TLS in order see the TLS potentials for archaeological areas.

2. TLS AS ARCHAEOLOGICAL DOCUMENTATION TOOL

One of the most referred, accepted and detailed categorization of survey techniques has been made by English Heritage (Bryan et al., 2009). With this study, all metric survey techniques are divided mainly two parts called “direct” or “indirect”. “Metric survey” can be defined as: the application of precise, reliable and repeatable measurement methods for heritage documentation (Andrews et al., 2009). These direct and indirect techniques are put together depending on final product, application areas, subject size and limitations in their use.

In recent years, 3D laser scanning shows great versatility for capturing any type of shape and speed of data acquisition. Definition of a laser scanner, adapted from (Böhler and Marbs, 2002) is ‘any device that collects 3D co-ordinates of a given region of an object’s surface automatically and in a systematic pattern at a high rate achieving the results in near real time’ (Böhler and Marbs, 2002). This device a kind of “robotic total station” for the mass capture of 3-D coordinate data known as “point cloud” using with rapid-range measurements(Andrews et al., 2009; Hassani, 2015).

Laser scanners have been used in many diverse applications in cultural heritage documentation depending on the purpose such as: structural or condition monitoring, deformation analysis, making record, spatial analysis, getting a digital geometric model and 3D model (Table 1; Heritage, 2011). They can be either small objects or complex buildings. Mainly three steps are followed with laser scanner:

-Field survey and data acquisition,
-Editing and data processing and
-Production of final data (Bryan et al.,2009).

Related to the size of the object, the point density becomes more significant. It’s possible to make survey from 1mm point density to 10 m (depending on the instrument capability).

Another key factor documentation with laser scanning is scale, the point density and the accuracy of measurement required by the project. A simple guide to appropriate point densities is given Table 1 (Bryan et al., 2009).

Point density/Rate of capture

Required distribution of measured points

scale	*point cloud*	*digitising**	*field survey†*
1:10	1mm	1–15mm	2–30mm (max 0.5m)
1:20	3mm	3–30mm	5–60mm (max 1m)
1:50	5mm	5–50mm	10–100mm (max 2m)
1:100	15mm	15–100mm	20–200mm (max 3m)
1:200	30mm	30–300mm	50–600mm (max 5m)
1:500	75 mm	75–750mm	0.1–1.5m (max 10m)

* From photogrammetric stereo model or point cloud: the higher value in each range represents the maximum permissible point interval.

† For example by electromagnetic distance measurement (EDM) or global positioning system (GPS). Where lines appear straight or detail is sparse the interval may be increased up to the maximum shown in brackets.

Table 1. Required distribution of measured points for photogrammetry, laser scanning, EDM or GPS techniques (Bryan et al., 2009)

3. ÇATALHÖYÜK ARCHAEOLOGICAL AREA

Çatalhöyük is one of the most ancient and prominent of the archeological sites in Turkey. It was built in the Neolithic period, and located near the town of Çumra district within the province of Konya, 52 km South east of the city (Figure 1-2).

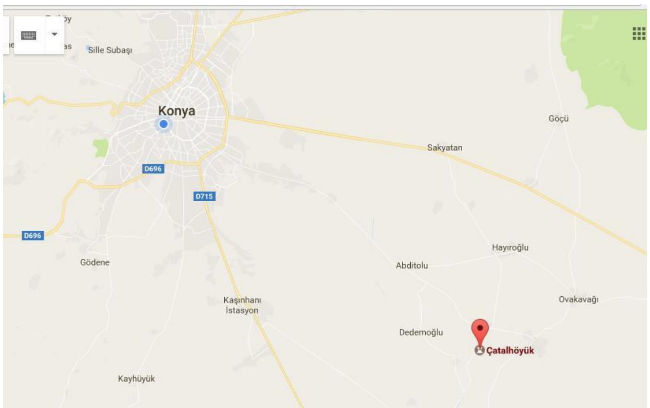

Figure 1. Çatalhöyük and Konya

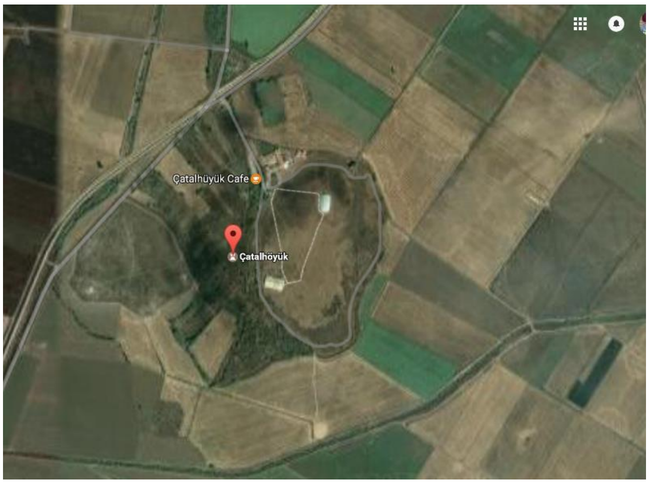

Figure 2. Çatalhöyük from the satellite (image from google earth)

Çatalhöyük consists of two hills form the 37 ha site on the Southern Anatolian Plateau. The taller eastern mound contains eighteen levels of Neolithic occupation between 7400 BC and 6200 BC, including wall paintings, reliefs, sculptures and other symbolic and artistic features. Together they testify to the evolution of social organization and cultural practices as humans adapted to a sedentary life. The western mound shows the evolution of cultural practices in the Chalcolithic period, from 6200 BC to 5200 BC (Figure 3). Çatalhöyük provides important evidence of the transition from settled villages to urban agglomeration, which was maintained in the same location for over 2,000 years. It features a unique streetless settlement of houses clustered back to back with roof access into the buildings (URL-1).

This site was first discovered in the late 1950s and excavated by James Melaart between 1961 and 1965 (Figure 4). The site rapidly became internationally famous due to the large size and dense occupation of the settlement, as well as the spectacular wall paintings and other art that was uncovered inside the houses. Since 1993, an international team of archaeologists, led by Professor Ian Hodder of Stanford University, has been carrying out new excavations and research, in order to shed more light on the people that inhabited the site. In July 2012, Çatalhöyük was listed on the UNESCO World Heritage List. The Turkish Cultural Foundation (TCF) has been a sponsor of the Çatalhöyük excavation project for multiple years. The TCF grants were allocated to build a shelter over the excavation site, and to help improve access and informational signage on the site. TCF worked with the Global Heritage Fund in California on this project. To further expand its knowledge on Çatalhöyük, TCF has been taking its Teacher Study Tours to Çatalhöyük for many years (URL-2).

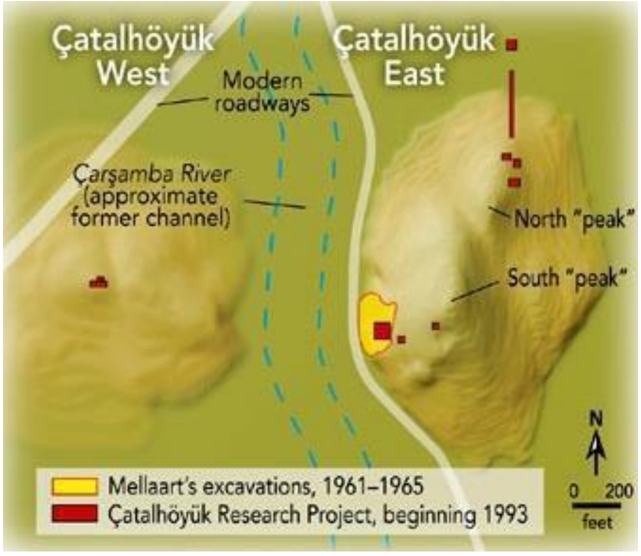

Figure 3. Site of Çatalhöyük, located in the semiarid Konya Basin of Anatolia (now central Turkey), comprises two mounds that accumulated as the settlement's inhabitants repeatedly built, tore down, and rebuilt their mud-brick houses. The eastern mound, dating from 9,400 until 8,000 years ago, has two "peaks," suggesting that the population may have been divided into two intermarrying kin groups. The western mound was occupied from about 8,000 until 7,700 years ago. Map by Joe Le Monnier (URL-3).

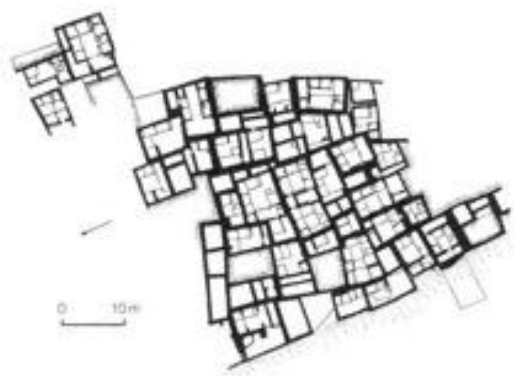

Figure 4. Plan of James Mellaart's excavations showing the dense house layout (URL-4)

3.1. Architecture in Çatalhöyük

One of Çatalhöyük's most defining attributes was its inhabitants' gradual, continuous building and rebuilding of their houses. These houses were very important to all aspects of their lives: material, social and ritual. Houses were roughly rectangular and closely built together with no streets in-between. Instead, people moved around on roofs and accessed their homes down a wooden ladder via an opening in the ceiling (URL-5).

All the houses found at Çatalhöyük are different in shape and size, yet most follow a general layout. Each central room had an oven below the stairs where people carried out domestic tasks such as cooking. Raised platforms within the rooms were used for sleeping and other domestic activities. Beneath these platforms inhabitants buried their dead. Side rooms were accessed off the central room providing essential storage areas (Figure 5).

Figure 5. A reconstruction showing the use of space and the layout of a typical house. Illustration by Kathryn Killackey (URL-5)

The case study was in Eastern Mound, North Peak where there is a big shelter on excavation area (Figure 6-7).

Figure 6. Excavation area of eastern mound, north peak

Figure 7. Excavation area of eastern mound, north peak

4. DATA CAPTURE AND PROCESSING

The scanning of the field was completed in one day and the whole area was covered with 12 scans. The scanning could be done only on the edges of the excavation area since it was forbidden to walk on the middle part of the archaeological area. Since the scanning was carried out only from the edges of the area, there were some missing parts in the data (Figure 14). Totally 515.726.448 million of points were acquired from 12 scan stations (Figure 10-11-12-13-14-15). The point spacing was 1-3 cm.

FARO Focus3D 120 was used for TLS survey. It is a phase-based laser scanner. It captures objects in range from 0.6 m to 120 m with distance accuracy up to ±2 mm. Similar to other phase-based scanners, it is characterized by a high measuring speed at a maximum of 976.000 measuring points per second. The scanner is equipped with an internal color camera. A built-in 8 mega-pixel HDR camera captures detailed imagery easily This integrarted colour camera is able to get photorealistic 3D colour scans with up to 70 megapixels resolution and parallax-free colour overlay to the scan data in exreme ligthining conditions (Figure 8). The GCPs were measured with RTK GPS (Real Time Kinematik Global Poistioning System) (Figure 9).

Figure 8. Terrestrial Laser Scanning with FARO Focus3D 120

Figure 9. GCPs GPS measurements

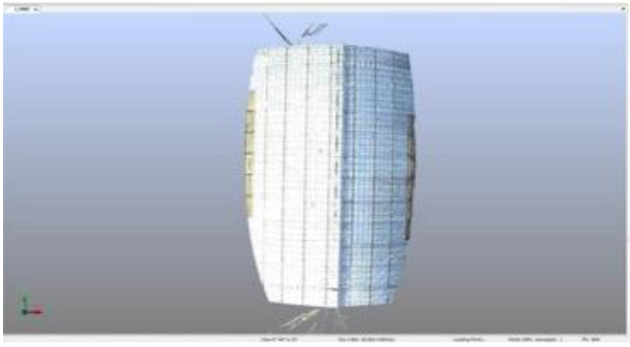

Figure 10. TLS data point cloud after the alignment in Scene software

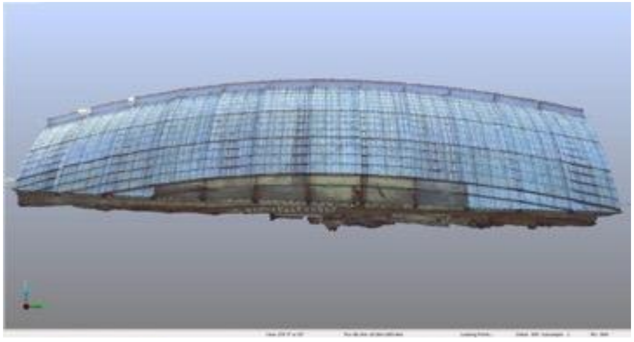

Figure 11. TLS data point cloud after the alignment in Scene software

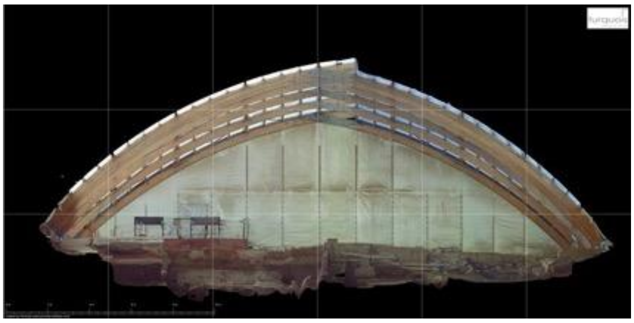

Figure 12. Cross section or archaeological area from TLS data point cloud data in Scene software

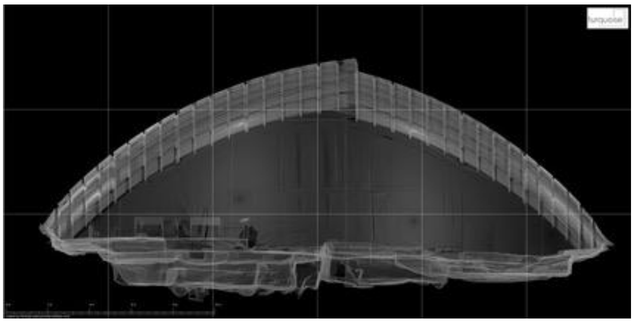

Figure 13. Cross section or archaeological area from TLS data point cloud data in Scene software

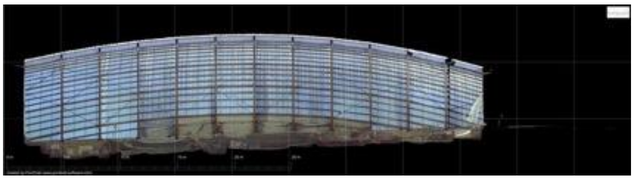

Figure 14. Longitudinal section or archaeological area from TLS data point cloud data in Scene software

Figure 15. Plan of archaeological area without shelter from TLS data point cloud data in Scene software

5. POTENTIALS AND LIMITATIONS OF TLS IN ARCHAEOLOGY

A wide range of use technologies applied in cultural heritage proved the variety of alternatives for documentation of an object. However, a single method is insufficient for the desired accuracy and each method has its own advantages and limitations. Cost, time, complexity and size of the object, accessibility, personal skills, instrument capabilities has a significant effect on choosing the most appropriate survey method. In most cases, it is needed to use a single method with the support of other techniques or a combination of different techniques in order to achieve result. If the budget allows, it is the most suitable solution and best possible method.

In order to acquire information in all survey processes require mainly on 3 issue:
-Understanding of techniques and their performance in terms of precision and accuracy
-Understanding of the subject of the documentation
-Presenting the information in accessible, clear and consistent way (Blake, 2010).

Even data capture techniques have increased there is still a lack of standards in data presentation AND 3d modelling for cultural heritage including archaeological areas. Today standards are as much about work practice as they are about listing quality constraints. The present suite of developing documentation technologies need expert guidance on their application and given the contraction of institutional support for sustaining metric skills.

Accessible technologies like laser scanner is known with its power for 3D data by heritage managers. The standards required to achieve conservation specific data from laser scanner are developing and the indications are that the "of the laser scan isn't a "magic tool" all in the sector.

However, TLS has been used for many tasks and great potentials in archaeology for:
-A detailed record of a site which helps to assist any intervention and analysis process,
-Working at different scales for archaeological features
-Structural or conditional monitoring and observing changes
-Detailed and achievable record of archaeological excavation areas or site at risk

-Supporting 3D models and animations for presentation of archaeological area through media or different technologies
-Supplying a digital geometric model for reconstruction or replica models in order to display or for virtual museums
-Helping the interpretation of archaeological features
-Spatial analysis with 3D data (Heritage, 2011).

As it was pointed out before, TLS or any method is not sufficient for a comprehensive documentation. It is always recommended to take photography, to take some measures manually, on-site drawings and other survey methods can be consulted and needed for better interpretation of the cultural heritage. Among the limitations;
-It doesn't provide unlimited geometric accuracy and completeness of the objects/areas. In many cases TLS can be unnecessarily expensive or redundant for requested output.
-Laser scanners are not always so variable or flexible as cameras for getting data. If high resolution is required for data, the time for acquiring data can take much more time than expected.
-During on-site working TLS cannot see through objects like dense vegetation. Besides they may have some problems of reflection related to object materials. In addition to all, health and safety precautions should be taken while using the equipment.
-For archaeological areas or objects, irregular edges may not be guaranteed as in precision. TLS, in general, is much more effective for recording of regular surface data. (Historic, 2018; Ruther et al., 2003). The areas with natural or unnatural obstacles, hidden or unseen points, objects with reflective materials are the reasons causing laser scanner fails to provide accurate data. Rainy weather condition and moisture affects the data as well. It still requires high cost, skilled operators and careful and relatively long data processing process (Amorim, 2011; Hassani, 2015; Heritage, 2011).

6. DISCUSSION AND CONCLUSION

This paper highlights the common use of TLS in archaeological area in order to get comprehensive and accurate data for archaeological areas. It's apparent that the use of TLS facilitates documentation process in many perspectives. However, in some special cases, like Çatalhöyük it may become insufficient for a detailed documentation.

In case study area, we were not able to get all data with TLS because of the prohibits on archaeological area. It was forbidden to walk or to put anything through the middle of the excavation area. Since the ruin is made of adobe, it is easily dispersible which it has to be very careful. So, we had to set up our scan stations close to the border or the area where, at the same time, close to the beginning of the shelter. It unfortunately caused lack of data. Also we couldn't get the certain edges of the ruins because of this limitation in data capture. We needed another technology to get aerial data. For this reason, our further research will be to use both TLS and UAV to acquire data of all area.

As another limitation, the GPS disconnected because of the shelter. While we could get GPS data outside, we were rarely, or sometimes not, able to get it. It changed also depending on our position inside.

During this case study, it became obvious that TLS cannot be a solution alone for a complete documentation. Beside its significant contributions to documentation and presentation of archaeological area, there are still some missing/need to develop parts in TLS pipeline, starting from data collection, including the type of the instrument, data processing, presentation and sharing.

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Author contributions

Conceptualization, Methodology, Writing-Reviewing, Field Survey,

Conflicts of interest

The authors declare no conflicts of interest.

Statement of Research and Publication Ethics

The authors declare that this study complies with Research and Publication Ethics

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