Cultural Heritage and Science
https://dergipark.org.tr/en/pub/cuhes
e-ISSN 2757-9050

Systematic analysis of the digital technologies used in the documentation of historical buildings

Fatma Zehra Çakıcı [1], Rabia Kaçdi [*2]

[1]Atatürk University, Faculty of Architecture and Design, Department of Architecture, 25240, Erzurum, Türkiye
[2]Atatürk University, Graduate School of Natural and Applied Sciences, 25240, Erzurum, Türkiye

Keywords
Digital Documentation
Digital Technology
Historical Building
Survey Methods
Photogrammetry

Research Article
DOI: 10.58598/cuhes.1344379

Received:16.08.2023
Revised:25.08.2023
Accepted:18.09.2023
Published:27.10.2023

Abstract

Cultural heritage buildings have values that provide a connection from past to present. The first stage of ensuring that these values are preserved and transferred to future generations is the documentation and diagnosis studies. The digital acquisition of the documentation data of historical buildings by digitizing, the creation of 2D drawings and 3D models with numerical data, provides an accurate analysis of the current situation of cultural heritage buildings and allows the evaluation of damage status of the building in the process after the documentation works. Although current studies in the literature mostly focus on the use of a certain method, device or software, it has been determined that there is no study that examines digital documentation methods in detail and systematically addresses the current technologies, programs and tools used in this process. Based on this gap in the literature, in this study, firstly, the documentation of cultural heritage and its importance are mentioned, the components of documentation are explained, and the methods, tools, applications and software programs that could be used in the documentation, recording and data processing of cultural heritage structures were systematically brought together. By comparing the data obtained as a result of this research study, in which the qualitative research method was used, with the documentation methods, it points out that digital documentation of cultural heritage structures allows for a more precise assessment by increasing the accuracy of data collection and analysis studies. The study also highlights the importance of the use of digital technologies, which makes it easier to store, share and manage the data at hand.

1. Introduction

Cultural heritage is a formation that reflects the unity of societies and strengthens society by keeping it together. Preserving the savings obtained from the past to the present is very important for the formation of future generations. Among the important resources we have learned about the cultural, social, religious and economic values of societies are immovable cultural heritage structures. The traces of these structures, which have been carried from the past to the present, are important memory elements that hold societies together as well as historical document values. The protection of immovable cultural heritage structures, which are important in establishing the connection between today and the past, is an important issue that requires interdisciplinary effort and work [1]. Works of cultural and historical value are damaged or even destroyed by natural disasters such as floods, fires, earthquakes, as well as environmental factors such as unconsciousness, wrong intervention and use, and climate change. As a result of the erosion and destruction of cultural heritage structures over time, the most important way to protect the structure in the most accurate way and to transfer it to future generations is restoration and conservation activities, and the first and most important step to guide these activities is documentation studies [2].

Cultural heritage constitutes the first stage of the conservation process of buildings and the stage of identification and documentation. Determination and documentation studies include determining the current status of the structure and obtaining the necessary data for other stages [1]. Expressing the current state of the structure in accordance with the drawing technique is defined as a survey. In this context, survey studies are the most important preliminary data of the documentation stage and guide other stages of the conservation process [3].

* **Corresponding Author**
*(fzehra.cakici@atauni.edu.tr) ORCID ID 0000-0002-4117-2058
(rabia.kacdi16@ogr.atauni.edu.tr) ORCID ID 0009-0005-0692-1067

Cite this article (APA);
Çakıcı, F. Z., & Kaçdı, R. (2023). Systematic analysis of the digital technologies used in the documentation of historical buildings. Cultural Heritage and Science, 4(2), 69-77

There are various methods used for survey taking in documentation studies. The methods to be used vary depending on the condition of the cultural heritage structure. The development of methods used in the process of documenting and diagnosing cultural and historical heritage is important both for the conservation practices to be carried out and in terms of archaeology, art history and architectural history [4]. The methods used in the documentation of cultural heritage structures and the analysis of data are gradually developing, and the traditional methods used in the diagnosis of the current state of their historical structures and in the preparation of survey projects are replaced by digital and advanced technical documentation methods with the developing technology [5-6].

Considering the degree of destruction, geometric structure and accessibility of the structure in the studies conducted with traditional documentation methods, these methods are often insufficient and the data obtained are limited to 2D drawings such as plans, sections and elevations. Digital methods allow 3D models and detailed visuals of the current state of the structure to be prepared with precise measurements [7]. Today, digital archiving of cultural heritage structures and 3D models are more preferred than traditional documentation methods. With the development of technology, many data collection tools are used in documentation studies [8]. Data collection devices such as digital aerial cameras, thermal cameras, panoramic cameras, digital cameras, satellite images, model helicopters are used instead of commonly used instruments such as tape measure, laser meter, nivo, theodolite. Today, photogrammetry (terrestrial photogrammetry and UAV photogrammetry) and the use of terrestrial laser scanning are among the digital documentation methods that have started to be used with the developing technology. The data obtained with these documentation methods enable the creation of 3D point clouds of cultural heritage structures [9]. It is seen that these methods are advantageous in terms of measurement accuracy, precision and time compared to traditional methods [10]. The tools to be used in order to make the most accurate data to be collected for the documentation studies of the historical structure should be selected correctly. In the methods to be used for documentation and diagnosis, features such as easy access to equipment, low rate/probability of making mistakes, technological data production, low cost are taken into consideration. Considering the condition and characteristics of the structure, it should be ensured that the most accurate equipment, application and the methods to be selected are compatible.

1.1. Conceptual Framework

It is very important to carry out documentation studies in the protection of cultural and historical heritage. Developing technology has brought along the digitalization of documentation methods. In this part of the study, it is aimed to evaluate the studies for the documentation of cultural heritage, the documentation methods used in the documentation of cultural heritage structures and the digital documentation methods.

Güleç Korumaz et al. [11] examined documentation, the importance of documentation, the components of documentation, the methods of documentation and digital documentation methods. Pakben [12] explained the traditional and advanced techniques used to document cultural heritage structures and applied them with examples. Letellier et al. [13] addressed the issues of documentation, recording and information management in the conservation of historical buildings. In this study, the documentation process, traditional and digital documentation methods were evaluated. Hamamcıoğlu Turan [14] discussed the architectural photogrammetry method, one of the contemporary documentation techniques, made examinations through sample photographs using film and digital cameras, scanners and image evaluation software, and discussed the advantages of the applications. Duran & Toz [7] discussed photogrammetry, one of the methods of documenting cultural heritage values, and focused on the 3Dization of the obtained data with photomodeler software and the compatibility of the obtained digital data with Autocad and 3DS max programs. In this way, he stated that the data obtained for documentation studies, which is an interdisciplinary field, is an environment that can be accessed directly or indirectly by people. Yakar et al. [6] obtained data with photogrammetry techniques by measuring with total station for the documentation of Emir Saltuk Tomb and obtained 2D and 3D drawings of the work by transferring the obtained data to the photomodeler program. Ulvi et al. [15] mentioned the methods of documentation and created the 3D model by producing the point cloud with the photogrammetric techniques of the Aksaray Red Church (using UAV). Tekinöz & Sağıroğlu [1] evaluated the use of different phone applications used for survey studies of immovable cultural heritage buildings in documentation studies. Kaya & Yiğit [16] studied to obtain a 3D model of the building from the photos obtained with digital cameras. In this context, it was emphasized in the study that digital handheld cameras were insufficient for inaccessible parts of the structure and precise detail measurements and the necessity of UAV technology. Yakar et al. [17] used Faro Scene, JRC 3D Reconstructor and Autodesk Recap software programs to 3D the data obtained in the documentation studies and made comparisons over the Obelisk sample.

Over time, developments have been made about the protection of cultural heritage structures, and in this direction, the concept of documentation has gained importance and new methods have been developed. During the literature review, it is seen that studies on the subject of digital documentation have increased in recent years and the subject remains up-to-date and important. In addition, in the studies examined in the literature, it has been determined that the documentation methods used to analyze historical buildings differ and develop with the development of technology. However, it has been determined that there is no study that examines digital documentation methods in detail and systematically addresses the current technologies, programs and tools used in this process while focusing more on the use of a certain method, device or software. Based on this gap in the literature, in this study, first of

all, the documentation of cultural heritage and its importance were mentioned, the components of the documentation were mentioned, and it was aimed to systematically address the methods, tools, software and application programs that can be used in the documentation, recording and data processing of cultural heritage structures.

1.2. Cultural Heritage and Conservation

Culture is a characteristic formation that contains all the values of a society materially and spiritually. There are many studies in the literature on the definition of the concept of "culture". The concept of culture in the dictionary is defined as "all the material and spiritual values created in the historical and social development process and the whole of the tools, hars, crops used in creating them and communicating them to the next generations, showing the extent of the sovereignty of man over his natural and social environment". The concept of heritage is defined as "what a generation leaves to the next generation". When both definitions are considered, cultural heritage can be considered as all of the material and spiritual values that societies leave for the next generations and it can be stated that societies assume the role of a bridge by keeping their past values alive in the present and future.

The concept of cultural heritage is a universal issue rather than nationality. Within the scope of the legal legislation on the protection of cultural heritage and its protection in a universal context, "Venice Regulation", "Convention on the Protection of the World Natural and Cultural Heritage", "ICOMOS", "ICOM", "Convention on the Protection of the European Architectural Heritage" and "European Convention on the Protection of the Archaeological Heritage" are some of them. According to the Turkish Law No. 2863 on the Protection of Cultural and Natural Heritage, "Cultural assets are all movable and immovable assets that are related to science, culture, religion and fine arts of prehistoric and historical periods or that have been the subject of social life in prehistoric or historical periods and have original scientific and cultural value above ground, underground or under water" (2863, article 3) [18]. Within the scope of this article, the main features of the works that are accepted as cultural assets and need to be protected are stated.

Cultural heritage buildings carry various values belonging to the period they were built and ensure that the values of the society in which they occur are kept alive. These are historical, social, cultural and architectural values. Cultural heritage are important values that enable the correct establishment of the knowledge transition between the past, present and future of the experiences and cultures of the people of the past throughout their lives. In this context, cultural heritage should be protected because it plays a role in the transfer of knowledge between generations, the protection and survival of cultural values, and adds historical depth to our perspective on life and guides us. Cultural heritage buildings that are already standing should be preserved, and besides, documentation studies should be carried out by investigating the structures that have lost or will lose their chance of preservation [19].

1.3. Documentation

Documentation, which is the first stage of cultural heritage conservation studies, is the physical definition of the current state of the structure in its most general definition [11]. Documentation is the recording and archiving of data obtained from cultural heritage works by various methods in order to ensure the transfer of information between generations. It is necessary for the preservation, survival, maintenance and control of the current work [20].

The documentation process of cultural heritage structures includes collaborative work of people who have knowledge/profession in different fields/disciplines [21]. Documentation studies starting with survey taking and visual studies are followed by damage analysis of the structure, material analysis and period analysis studies within the scope of analytical survey. The survey is the expression of the current state of the structure in accordance with the drawing technique. In this context, the survey is defined as "drawing documents that are prepared to describe the current situation of the whole or part of the structure or group of structures at certain scales and do not contain any comments or evaluations" [22]. Survey studies are the most important preliminary data of the documentation process and constitute a basis for damage analysis, restitution and restoration projects [4]. Survey drawings include layout plan, floor plans, ceiling plans, sections and elevation drawings, damage analysis, material analysis and 3D model of the structure. With the analytical survey studies, the work is examined in more detail and conservation decisions are taken in this direction [23].

The documentation process consists of two stages. These are the registration process and the documentation process. The registration process, which is the first stage, is the process of investigating what is necessary for the documentation of the cultural heritage work and the known information about the work. The second stage is the documentation process, which includes studies involving the recording of the data obtained in the registration process with the documentation methods selected in accordance with the work (Figure 1).

1.3.1. Importance of Documentation

With the documentation of a cultural heritage structure;

- The current status of the structure is recorded and defined.
- The current damage status of the structure is determined.
- By documenting the current state of the structure, a new function can be defined for use.
- Documentation studies, which constitute the first stage of conservation activities, form the basis for other stages (restitution, restoration) [3].
- Documentation studies are carried out in the digital environment and the data of the structure can be used by different disciplines and it sets an example for people who want to work [25].

• It carries the message of cultural heritage and itself from the past to the future and ensures that it is transferred to future generations in a sustainable way [23].

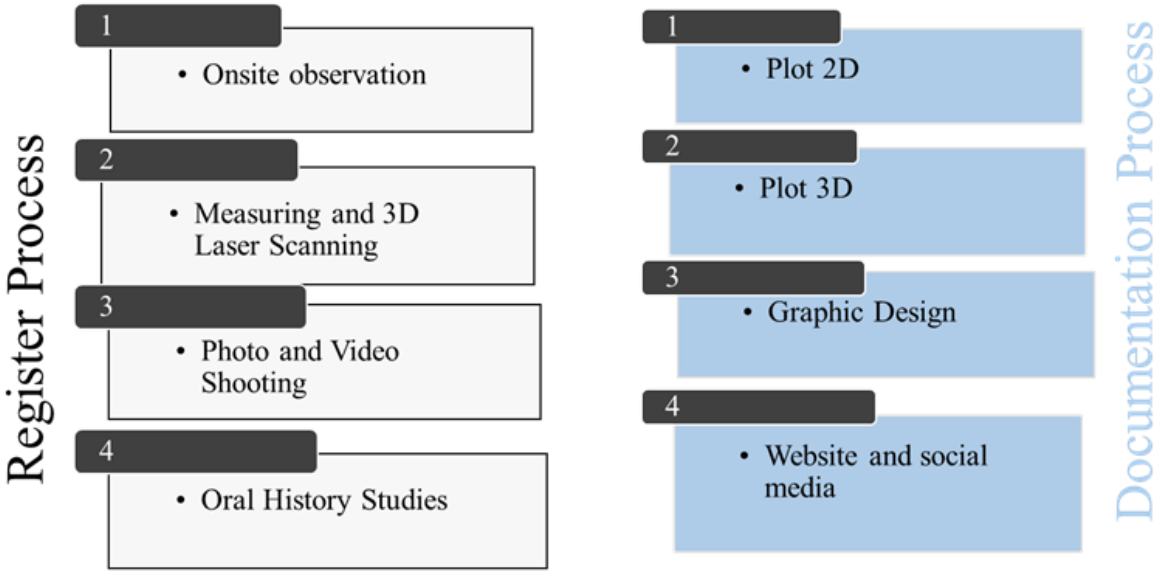

Figure 1. Registration and documentation process [24].

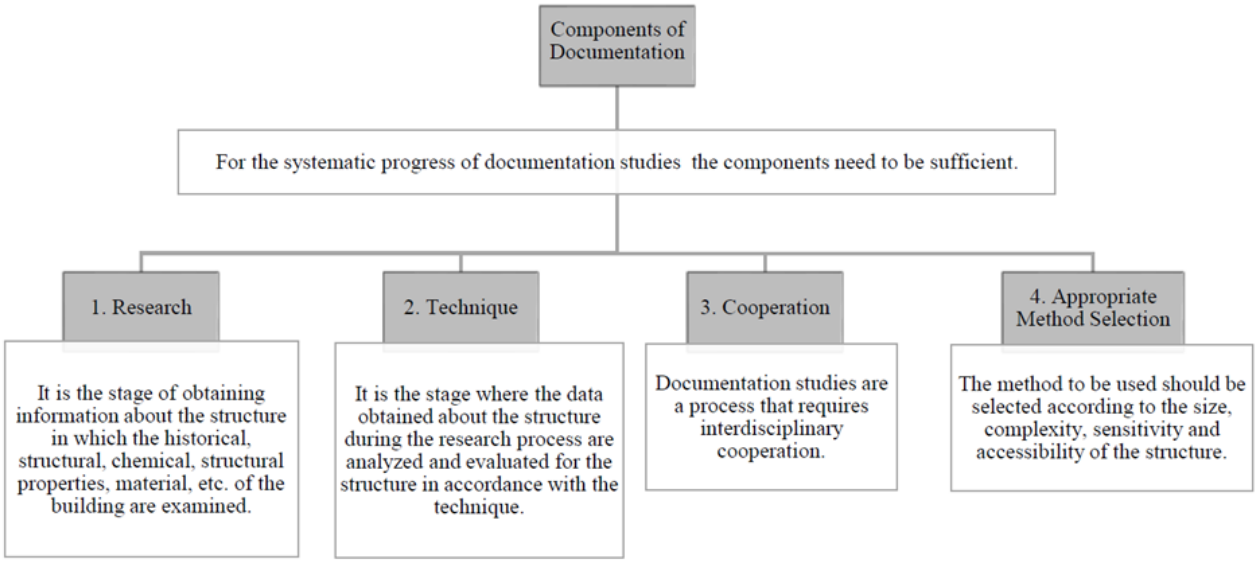

Figure 2. Components of documentation [12].

1.3.2. Components of Documentation

More than one component plays a role in the process of performing documentation studies (Figure 2). The fact that all components are complete and that studies are carried out with the right method will increase the accuracy and value of documentation studies.

2. Method

As a research method, a conceptual framework was created within the scope of the research, and a literature review was conducted on cultural heritage, documentation and documentation methods, and qualitative research method was adopted in the study. In the light of the data obtained, traditional and digital documentation methods have been evaluated and the methods, tools, software and application programs that can be used in the documentation, recording and data processing of cultural heritage structures have been systematically brought together.

3. Results

3.1. Methods used in documentation

In order to carry out documentation studies, it is necessary to obtain a large number of data and to process the obtained data. Conducting these studies requires interdisciplinary cooperation and technical work. In this context, the workflow consisting of survey, restitution and restoration stages should be planned and proceeded in the most accurate way.

There are different methods for survey studies, which form the basis of documentation and are the first stage of the process (Figure 3). Methods used for obtaining data in documentation can be classified as;

1. Oral-written documentation

2. Visual documentation
3. Documentation by measurement techniques
4. Documentation based on scanning
5. Software and application programs

Various software and application programs are also used to process the obtained data, transfer it to digital media, create 2D and 3D drawing documents and make interdisciplinary sharing.

<table>
<tr><th>1. ORAL -WRITTEN DOCUMENTATION METHODS</th><th colspan="2">2. VISUAL DOCUMENTATION METHODS</th><th colspan="2">3. DOCUMENTATION METHODS WITH MEASUREMENT TECHNIQUES</th><th>4. DOCUMENTATION METHODS BASED ON SCANNING</th><th>SOFTWARE-APPLICATION PROGRAMS</th></tr>
<tr><td rowspan="4">Written Documents
Drawing Documents
Graphic Documentation (with drawing)
Information forms</td><td colspan="2">Digital Handheld Cameras
Cameras
Smartphone Apps</td><td>Traditional Measurement Methods</td><td>Digital Measurement Methods</td><td rowspan="4">The global measurement coordinate system (Nivo
Theodolite
Total station
3D laser scanner Terrestrial laser scanning)
Airborne Laser Scanning (LIDAR)
Underground Radar (Geo-radar scanning) (Ground-penetrating radar (GPR))
Bathymetric (Submarine)</td><td rowspan="4">-Faro (Scene)
-Topcon (Scan master)
-Lieca (Geosystem hds cyclone)
-Riegl (Riscan)
-Netfab (Flexscan 3d)
-Minolta (Polygon)
-Surphaser (Geomagic, surph view, inventor autodesk)
-Trimble (LFM ve realwork)
-Z+F imager (LFM) - Stonex (Reconstructor)
-Maptek (I-Site Studio Software)
- Polywork
-Point Cab
-JRC 3D Reconstructor
- Autodesk Recap
-Photomodeler program
-PİX4D program
-Agisoft program
-3D Reshaper program
-HBIM (BIM for Heritage)</td></tr>
<tr><td colspan="2">Photogrammetry</td><td rowspan="3">Tape Measure
Jalon
Water balance
Plumb
Waterspout
Measuring plug</td><td rowspan="3">Laser meter
Smartphone Apps
-Easy measure
-Laser type (laser ruler)
-Cam measure
-Tape measure
-Ruler phone
- Photo ruler ABC
-My measures
-Magic plan</td></tr>
<tr><td>Aerial Photogrammetry (Balloon, Airplane, Model Airplane, Model Helicopter)</td><td>Terrestrial Photogrammetry</td></tr>
</table>

Figure 3. Documentation Methods.

3.2. Technological/Digital documentation process

Recent technological developments have brought along the development of methods used in the documentation and diagnosis of cultural heritage structures. Traditional documentation methods are being replaced by digital documentation methods along with technological developments and are progressing rapidly. Digital methods have more advantages than traditional methods. It enables easier and more precise measurements to be made in determining and documenting the current state of the structure, enabling more accurate data to be obtained and is advantageous in terms of time.

In digital documentation methods, studies are carried out by choosing the most appropriate method for the current situation of the structure. The digital documentation process starts with the definition of the structure, the parametric object library of the structure is created and continued, and documentation work is carried out by creating 2D drawings and 3D models (Figure 4).

3.2.1. Registration process: Visual and/or numerical documentation methods

The first stage of the documentation process is to obtain data using visual and numerical documentation methods. In this process, interior places and exterior of the structure is visually documented with the help of smartphone cameras, digital handheld cameras and cameras as well as advanced technical methods of photogrammetry enhancing more professional ways of taking photographs of the structure (Figure 5).

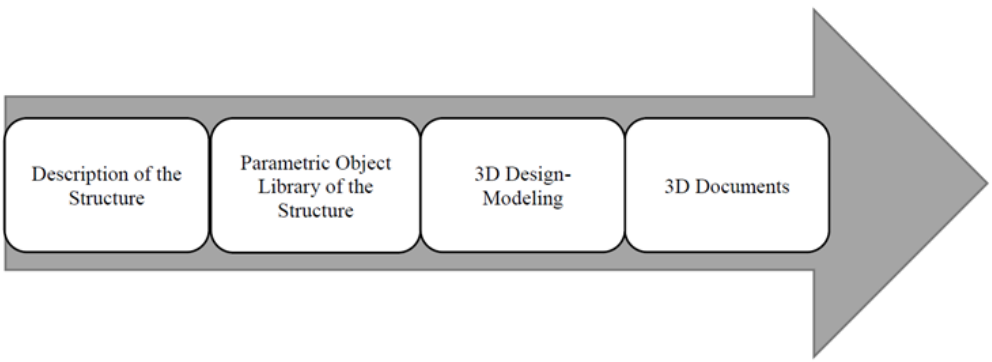

Figure 4. Digital documentation process.

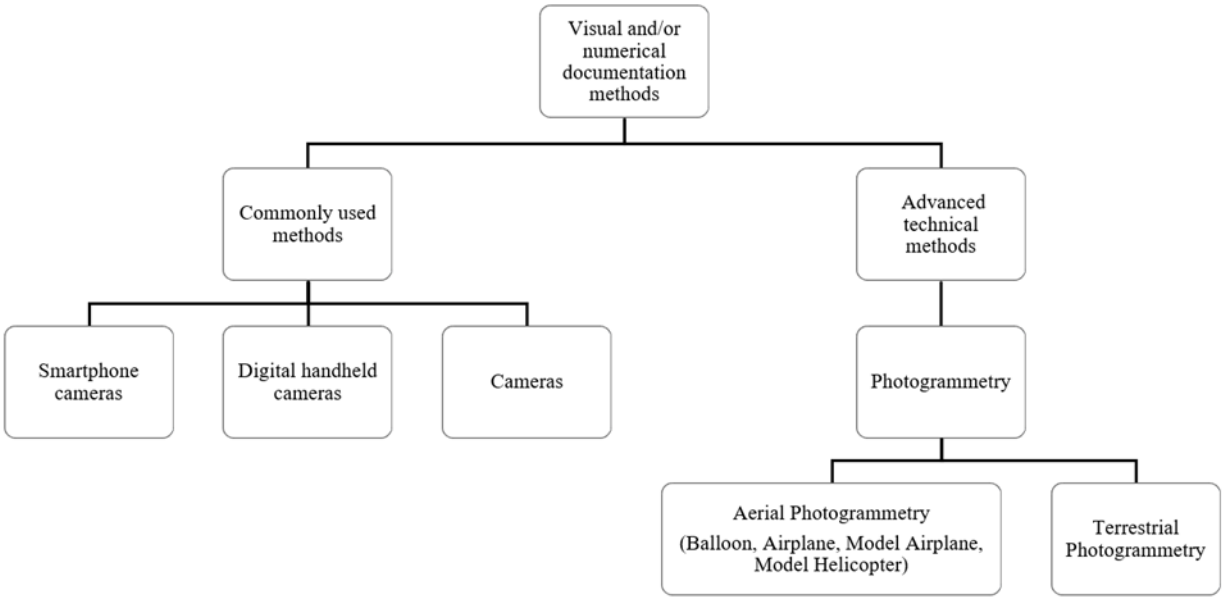

Figure 5. Visual/Numerical documentation methods.

3.2.2. Recording process: Methods of measurement

The second step of the documentation process consists of obtaining information about the structure and the data of its current status. In this context, this stage focusses on surveying process of the structure with the help of measurement studies. Traditional measurement methods include traditional instruments like tape measure, jalon, water balance, plumb, measuring plug etc. On the other hand, there are increasing number of technological/digital measurement methods ranging from laser meter and smartphone applications to the global measurement coordinate system, airborne laser scanning, underground radar, bathymetric measurement methods (Figure 6).

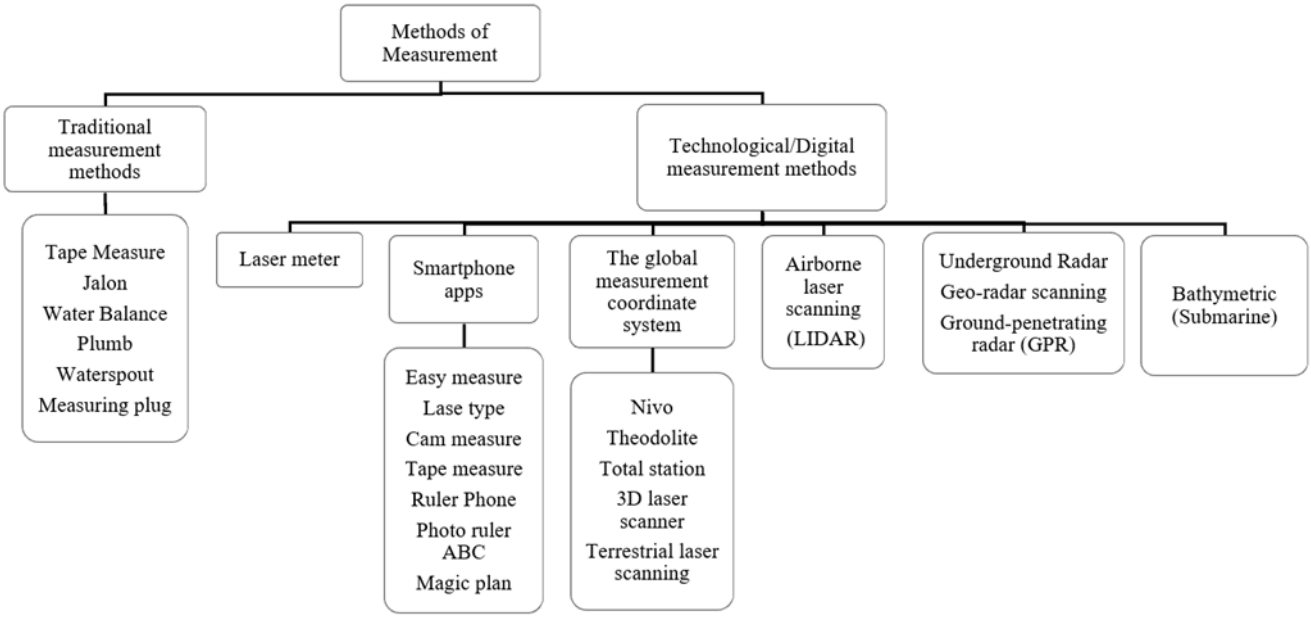

Figure 6. Methods of measurement.

3.2.3. Documentation process: Data processing methods/programs

The data processing stage in which the data obtained during the survey process is digitized constitutes the final stage of the documentation studies. Data sources may be damaged during the digitization process of the obtained data. In this context, hardware and software programs are needed for the transfer and availability of digital documents to future generations [26]. The programs used in digitization differ according to the methods used to obtain the data and the documents required for the work. Photomodels, Faro Scene, Autodesk Recap, JRC 3D Reconstructor, 3D Reshaper, HBIM are commonly used software in the processing of the obtained data. Each software works with different methods, but the working method of all of them is the processing of photogrammetric research data. Photomodels software provides 3D data and images from photos and videos, while Autodesk Recap, JRC 3D Reconstructor are photogrammetric software that create 3D models that work with laser scanners that scan

photos and videos as well as 3D. In addition, the Faro Scene software has been developed for Faro Focus and 3D laser scanning devices. HBIM software covers not only the documentation of the current status of the cultural heritage structure, but also the deterioration of the structure over time and the evaluation of the interventions to be made to the structure. In this context, the data processing methods and programs actively used today are summarized in Figure 7.

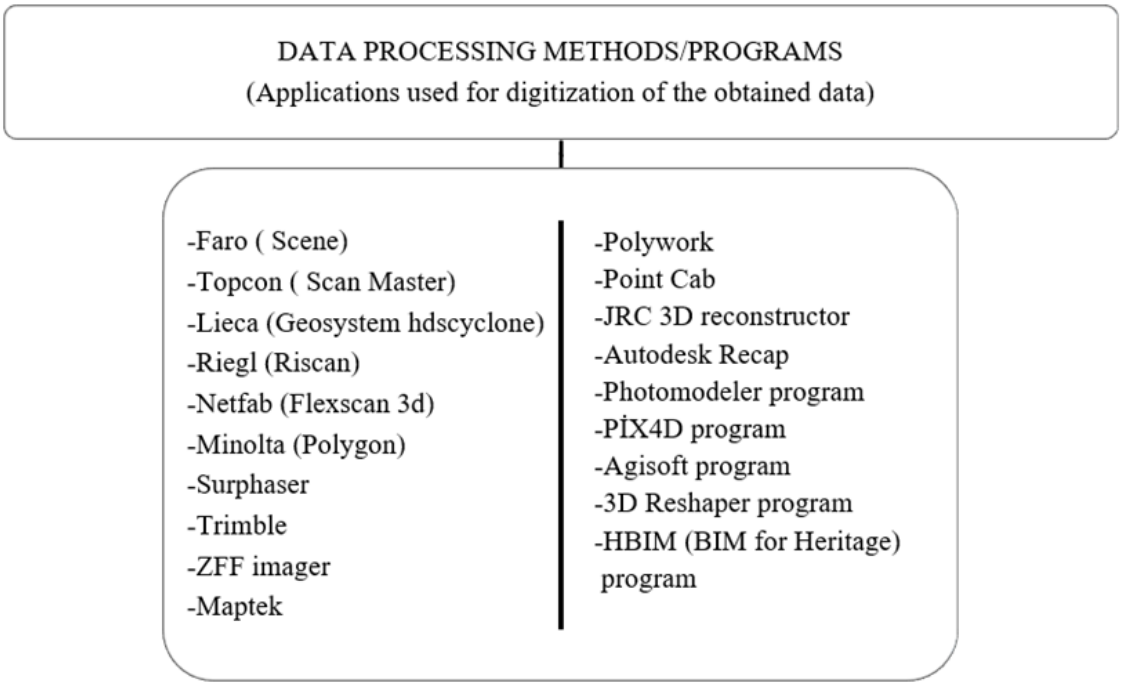

Figure 7. Data Processing Methods/Programs.

4. Discussion and Conclusion

The data obtained by using traditional methods in the documentation studies of cultural heritage structures allow the creation of more 2D documents of the structure. However, traditional methods are not always sufficient in documenting cultural heritage structures and obtaining all the data of the structure in survey measurements. Using traditional documentation methods in the documentation of large-scale cultural heritage buildings, which are difficult to reach, located on narrow streets, have a high level of destruction, and are composed of complex geometric shapes, causes problems in terms of time and workforce. Traditional methods used can make data consistency difficult, increase the error rate in the evaluation results and cause errors in the process of making decisions for restoration.

Digital documentation of cultural heritage structures allows for a more precise assessment study by increasing the accuracy of data collection and analysis studies. The use of digital technologies also makes it easier to store, share and manage the data at hand. Measurements of geometric shapes such as domes, arches, etc. encountered in the historical structure with digital documentation techniques can be made in a short time by giving more accurate measurement results in the regions that are difficult to reach in the structure and need to be measured by installing a scaffold. With digital documentation methods such as photogrammetry to be used, in a short time, the documentation data of the structure can be obtained with studies with less workforce, and by creating 3D models with software programs, the damages that occur in the structure and will occur over time can be determined and the appropriate intervention method can be selected [27]. As a result of the digital documentation process consisting of various stages, architectural model of the building in virtual reality and animation videos with virtual tour are obtained. With the use of virtual models and virtual tours, access to the information of the structures with limited access will be facilitated, interdisciplinary information exchange could be given an opportunity and the structures could be analyzed [28]. The digital documentation methods used (photogrammetry, 3D laser scanning, software programs) can work in harmony with each other and the data obtained can be easily shared by different occupational disciplines. With digital technologies such as laser scanners and UAV technology, point clouds of the structure are obtained. In this way, orthophotos and panoramic images of the structure are obtained and a connection is established between 2D and 3D data [29]. Digital methods are used not only in building scale but also in documenting complex structures and archaeological sites. Periodic analyses can be made by obtaining drawings and models of the layers of structures and archaeological areas containing different periods in 2D and 3D [30].

Accuracy is one of the most important factors in documenting the current status of the work. The accuracy of the 3D documents to be created for the artifact is important for the preservation of the historical structure to be transferred to future generations. The software used in the data processing process following the data acquisition stage, which is the first stage of documentation, should ensure the sensitive processing

of the scan data. Software programs covering the creation of the 3D model, restitution and restoration works may differ according to the structure and required documents. Photomodels, Faro Scene, Autodesk Recap, JRC 3D Reconstructor, 3D Reshaper, HBIM are the most preferred software programs today.

Digital systems based on today's technology are also widely used in modern building production and every stage of the construction process can be calculated in advance. It is even seen that, thanks to digital systems, building production is done using 3D printers. In this context, it is thought that the use of digital systems will provide important usage opportunities for data collection, modeling and analysis of historical buildings in different scenarios [31].

As a result, with the development of technology, the emergence of different methods, tools, applications and software allows the use of alternative methods in documentation studies. Choosing the appropriate methods for the needs and requirements of the structure will be important in the accuracy of the resulting products. Adapting to the developing technology in the field of documentation and following the increasing number and types of digital technologies and developments are among the primary tasks of the actors involved in the process, especially architects.

Author contributions

Fatma Zehra Çakıcı: Conception of idea, introduction, methodology, analysis and discussions, conclusions, writing-reviewing and editing. **Rabia Kaçdi:** Literature review, data collection, analysis and discussions, writing-original draft preparation.

Conflicts of interest

There is no conflict of interest between the authors.

References

1. Tekinöz, E. & Sağıroğlu, Ö. (2018). Taşınmaz Kültür Varlıklarının Belgelenmesinde Akıllı Cep Telefonu Uygulamalarının Ölçüm Amaçlı Kullanılabilirliğinin Tespiti. Tübav Bilim Dergisi, 11(4), 1-13.
2. Ulvi, A. (2008). Antik Tiyatroların Fotogrametrik Rölöve Planlarının Çıkarılması Üzerine Deneysel Bir Çalışma. Yüksek Lisans Tezi, Selçuk Üniversitesi Fen Bilimleri Enstitüsü Fotogrammetri Anabilim Dalı, Konya.
3. Güleç, S. A. (2007). Yersel Fotogrametri Yöntemi ile Rölöve Alım Tekniğinin Taç Kapılarda Uygulanışı Konya Örnekleri. Yüksek lisans tezi, Selçuk Üniversitesi Fen Bilimleri Enstitüsü, Konya.
4. Turan, M. H. (2004). Mimari Fotogrametri Alanındaki Çağdaş Gelişimlerin Değerlendirilmesi, Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi, 19(1).
5. Coşgun, N., Çügen, F. ve Selçuk, S. (2021). A Bibliometric Analysis on Heritage Building Information Modelling (HBIM) Tools, ATA Planlama ve Tasarım Dergisi, 5-2, 61-80.
6. Yakar, M., Kabadayı, A., Yiğit, A.Y., Çıkıkcı, K., Kaya, Y. & Catin, S.S. (2016). Emir Saltuk Kümbeti Fotogrametrik Rölöve Çalışması ve 3Boyutlu Modellenmesi. Geomatik, 1(1), 14-18.
7. Duran, Z., & Toz, G. (2003). Tarihi Eserlerin Fotogrametrik Olarak Belgelenmesi ve Coğrafi Bilgi Sistemine Aktarılması, İTÜDERGİSİ/d, 2(6).
8. Varol, F., Yiğit, A.Y. & Ulvi, A. (2021). Kültürel Mirasın Dijital Ortamda 3 Boyutlu Arşivlenmesi: Maghoki-Attar Camii Sanal Model Örneği. Turizm Akademik Dergisi, 8(1), 181-191.
9. Barrazeti L (2016). Parametric as built model generation of complex shapes from point clouds. Advance Engineering Informatic, 30(3), 298-311.
10. Çelik, M.Ö., Alptekin, A., Ünel, F.B., Kuşak, L., & Kanun, E. (2020). The Effect of Different Flight Heights on Generated Digital Products: DSM and Orthophoto. Mersin Photogrammetry Journal, 2(1), 1-9.
11. Güleç Korumaz, A., Dülgerler, O. N. & Yakar, M. (2011). Kültürel Mirasın Belgelenmesinde Dijital Yaklaşımlar. Selçuk Üniversitesi Mühendislik, Bilim ve Teknoloji Dergisi, 26 (3), 67-83.
12. Pakben, U. (2013). Tarihi Yapıların Rölöve ve Analizlerinde Kullanılan İleri Belgeleme Teknikleri, Doktora Tezi, DEÜ Fen Bilimleri Enstitüsü, İzmir.
13. Letellier, R., Schmid, W. & LeBlanc, F. (2007). Recording, Documentation, and Information Management for the Conservation of Heritage Places: Guiding Principles. Los Angeles, CA: Getty Conservation Institute.
14. Hamamcıoğlu Turan, M. (2013). Mimari Fotogrametri Alanındaki Çağdaş Gelişimlerin Değerlendirilmesi. Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi, 19(1).
15. Ulvi, A., Yakar, M., Yiğit, A. Y., & Kaya, Y. (2020). İHA ve Yersel Fotogrametrik Teknikler Kullanarak Aksaray Kızıl Kilise'nin 3 Boyutlu Nokta Bulutu ve Modelinin Üretilmesi. Geomatik, 5(1), 19-26.
16. Kaya, Y., & Yiğit, A.Y. (2020). Dijital El Kameraları Kullanılarak Kültürel Mirasın Belgelenmesi, Türkiye Fotogrametri Dergisi, 2(2), 33-38.
17. Yakar, İ., Çelik, M. Ö., Hamal, S.N.G. & Bilgi, S. (2021). Kültürel Mirasın Dokümantasyonu Çalışmalarında Farklı Yazılımların Karşılaştırılması: Dikilitaş (Theodosius Obeliski) Örneği. Geomatik, 6(3), 217-226.
18. T.C. Kültür ve Turizm Bakanlığı, Kültür Varlıkları ve Müzeler Genel Müdürlüğü, Türkiye Geneli Korunması Gerekli Taşınmaz Kültür Varlığı İstatistiği, https://kvmgm.ktb.gov.tr/TR-44798/turkiye-geneli-korunmasi-gerekli-tasinmaz-kultur-varligi-istatistigi.html
19. Gümüşçü, O. (2018). Tarihi Coğrafya ve Kültürel Miras, Erdem, (75), 99-120.
20. Ortiz, P., Sánchez, H., Pires, H., & Pérez, J. A. (2006). Experiences about fusioning 3D digitalization techniques for cultural heritage documentation. In ISPRS, Commission V Symposium, Image

Engineering and Vision Metrology, Dresden (Germany) (pp. 25-27).
21. Soler, F., Melero, F. J., & Luzón, M. V. (2017). A complete 3D information system for cultural heritage documentation. Journal of Cultural Heritage, 23, 49-57.
22. TMMOB Mimarlar Odası Taşınmaz Kültür Varlıklarının Rölöve, Restitüsyon ve Restorasyon Projelerine İlişkin Teknik Şartname, Kabul tarihi: 28.12.2011, MYK no: 42/31.
23. Kuban, D. (2000). Tarihi Çevre Koruma ve Onarımın Mimarlık Boyutu Kuram ve Uygulama, Yapı Endüstri Merkezi Yayınları, İstanbul.
24. Ballice, G., Paykoç, E., & Güler, G. (2020). 2 Documenting Modern Interiors using Digital Technologies: Mid-Century Apartment Buildings in İzmir. New Approaches in Contemporary Architecture and Urbanism, 11-22.
25. Haddad, N.A. (2011). From Ground Surveying to 3D Laser Scanner: A Review of Techniques Used for Spatial Documentation of Historic Sites. Journal of King Saud University-Engineering Sciences, 23(2), 109-118.
26. Simon, A., & Kiszl, P. (2021). Aspects of the Long-Term Preservation of Digitized Catalogue Data: Analysis of the Databases of Integrated Collection Management Systems. Preservation, Digital Technology & Culture, 50(2), 51-64.
27. Remondino F., El-Hakim S., 2006, "Image-Based 3d Modelling: A Review", The Photogrammetric Record, 21(115), 269- 291.
28. Lasorella, M., Cantatore, E., & Fatiguso, F. (2021). Smart approaches to enhance technical knowledge of in/low-accessible heritage. SCIRES-IT-SCIentific RESearch and Information Technology, 11(2), 97-112.
29. Cianci, M. G., & Colaceci, S. (2023). Laser Scanner and UAV for the 2D and 3D Reconstructions of Cultural Heritage. SCIRES-IT-SCIentific RESearch and Information Technology, 12(2), 43-54.
30. Diker, H. F., & Esmer, M. (2021). Preliminary Evaluation of the Terrestrial Laser Scanning Survey of the Subterranean Structures at Hagia Sophia.Preservation, Digital Technology & Culture, 50(2), 65-84.
31. Ata, S. & Dereli, M. (2023). 3D Yazıcı Malzemesi Beton ve Bileşenlerini Kullanarak Yapı Üretimi, 9. Uluslararası Mühendislik ve Teknoloji Yönetimi Kongresi, 29 Nisan - 01 Mayıs 2023, s. 728-738