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*Research Article*

# GIS AND THREE-DIMENSIONAL MODELING FOR CULTURAL HERITAGES

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**ABSTRACT:** Cultural heritages are the history of the nations, and history forms the identities of the nations. Therefore, protection of cultural heritages means protection of the history and identity of the nations. Identification of the current status of cultural heritages is important for documentation, preservation, and for use as a base for restoration. Documentation studies need robust and scientific methods. GIS and photogrammetry have recently been the most commonly used scientific methods for documenting cultural heritages. The aim of this study is investigate the photogrammetric method and GIS for documentation of cultural heritages digitally. In documentation studies, digital terrestrial photogrammetry is one of the main methods of processing information of historical monuments on computers according to GIS and documenting it in three dimensions. In this study for documentation, all data of 46 historical monuments located in Silifke/Mersin were collected and transferred to a database so that it is made queryable. Some of those heritages were reconstructed as 3D models by the use of photogrammetric techniques. Finally, 3D Models were integrated into the system for presentation.

***Keywords:*** *GIS, photogrammetry, historical monument, 3D modeling*

## 1. INTRODUCTION

Cultural heritage structures play an important role in sustaining the relationship between human beings and their past. To preserve cultural heritage assets for the next generations, fast and accurate documentation of structures and their surrounding areas on the basis of scientific techniques needs to be developed (Kivilcim & Duran, 2016). Cultural heritages are the history of nations, and history forms the identity of the nations. Therefore, protection of cultural heritages means protection of the history and identity of the nations. Identification of the current status of cultural heritages is important for documentation, preservation, and use as a basis for restoration. The topic of the documentation and conservation of cultural heritages is well established in the contemporary society (Lezzerini et al., 2016). Well documentation is necessary, not only for generations, but also in functionality in contemporary usage and re-evaluation of the historical buildings. Cultural heritages due to have their different natural characteristics, different sizes, and complicated structure they require more sophisticated measurement tools and techniques to documentation (Ulvi & Toprak, 2016).

Traditional geodetic surveying and conventional architectural representation are typically 2D visualizations of an object that consist of plans, sections, profiles, and rectified images. To understand the object comprehensively, it is necessary to extract 2D information and build a 3D geometry simulation in the mind (Hanan et al., 2015). A series of photos of an object can be sufficient for constructing a 3D model of the object. The technique for such reconstruction, called photogrammetry, has been used profusely in graphical and numerical documentation of cultural heritages, particularly in historical buildings (Reinoso et al., 2014). Photogrammetry is an independent method in the documentation process. This method is based on at least two images with overlapped data, which guarantee the triangulation process. The aim of digital close-range photogrammetry is to make the process of recording and processing data simpler and faster. The method is an accurate technique for documenting color and texture and providing metric data of objects with different size and complexity in a relatively short time. This technique can be used when access to the object is limited or when the direct measurement of the object would threaten it (Hassani, 2015). Photogrammetry uses only photographs and mathematical equations. These are important for correct and accurate measurements of cultural heritage sites (Yilmaz et al., 2007). Photogrammetry can significantly cut the time spent on developing the documentation and conservation plans (Waas & Zell, 2013). It provides a resource for faithful restoration of the artifact in case of any damage or destruction due to possible natural disasters or physical interventions (Şasi & Yakar, 2018).

GIS includes software and hardware tools and a group of procedures elaborated to facilitate the capture, editing, administration, manipulation, analysis, modeling, representation and the exit of spatial referenced and semantic data, to solve any type of planning, administration, storage, and further information concerning the problem. GIS technology greatly facilitates the inventory, evaluation, preservation, and documentation of archaeological sites and historical structures. As heritage conservation is becoming more holistic and historic sites are steadily becoming integrated with the surrounding landscapes, GIS is being recognized as a critical component in the development of virtual historic collections and archives (Toz & Duran, 2004).

This paper presents a study about documentation method that aiming to protect of the cultural heritages and to ensure their sustainability. In the documentation study, an inventory has been created as attribute data, and spatial data has been produced (point, line, and polygon). Finally, 3D models of some cultural heritages have been generated, and all data have been integrated into the GIS.

## 2. MATERIALS AND METHODS

The following activities were performed in the scope of this study; data acquisition, design of GIS and photogrammetric works.

### 2.1 Data acquisition

Before the data were acquired in the field, the study area was detected as Silifke/Mersin in Turkey because of its rich historical potential. The information of cultural heritages of this city, such as position, age, and historical information, was researched from different sources (web sites, local government, museums, books, citizens, and others). In the light of this research, 46 cultural heritages have been detected, and a route plan has been prepared. A Canon PowerShot SX 220 HS digital compact camera, a Topcon GPT 3007 Total Station and a Magellan SporTrak Pro hand-held GPS device were provided to collect data from the field. All the cultural heritages were visited according to the route plan, and photographs were taken while coordinates were entered into the ITRF96 Datum by the hand-held GPS device. It is seen in the investigation and detection studies that the cultural heritages of Silifke are mostly from the Hellenistic, Roman, and Byzantine periods. The monumental tombs built in those times were better able to withstand the elements than the remains of the other heritages. The ancient cities are in ruin, and only piles of stones are in view now.

### 2.2 Design of the GIS

Information system has been designed by ArcGIS software. Silifke district boundary has been digitized with Polygon Tools, all the roads have been digitized with Polyline Tools, and all the settlements, villages and location of cultural heritages have been positioned with Point Tools (Figure 1). Acquired coordinates of cultural heritages have been imported from the field into the system. All those data have been input to an Excel table to create a database. All study in ArcGIS were carried out in WGS84 Datum, so acquired coordinates from the field in ITRF96 has been converted to WGS84.

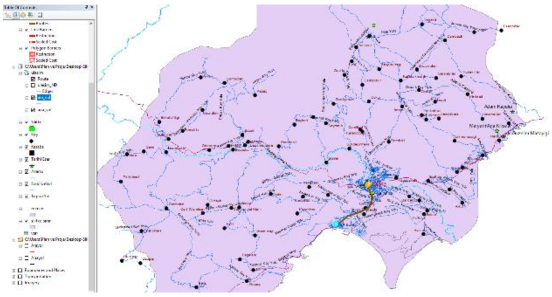

Figure 1. Digitized boundary, roads, streams, and settlements

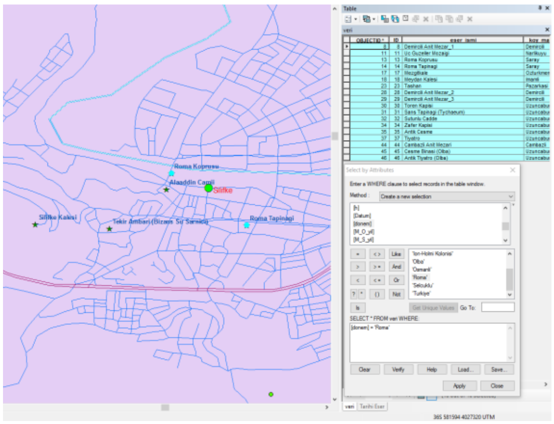

Figure 2. Query of Roman period cultural heritages by using Select by Attributes menu

A table has been compiled with these columns: ID, cultural heritage name, settlement, elevation, period, year, century, architecture, restoration year and restorer (Figure 3). A network dataset has been created to solve the shortest distance to the cultural heritage from any point. Street names, types, and directions (one way or double) have been input, one by one, to the 3757 polyline for accurate navigation. The system was made operational by using many network analysis tests in different query probabilities. In addition, every digital object was created with the database table. Having multiple tables prevents duplicating information in the database, because the information is stored only once in one table (URL-1). Database tables have been related to

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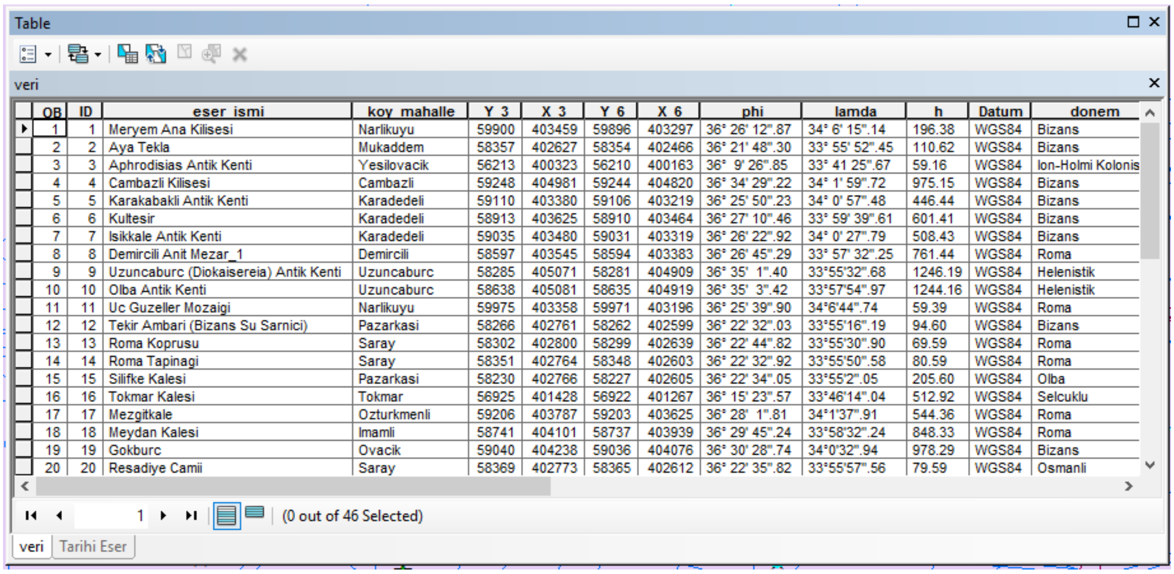
each other to pull the data together in meaningful ways.



Table

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| OB | ID | eser_ismi | koy_mahalle | Y_3 | X_3 | Y_6 | X_6 | phi | lamda | h | Datum | donem |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | Meryem Ana Kilisesi | Narlikuyu | 59900 | 403459 | 59896 | 403297 | 36° 26' 12".87 | 34° 6' 15".14 | 196.38 | WGS84 | Bizans |
| 2 | 2 | Aya Tekla | Mukaddem | 58357 | 402627 | 58354 | 402466 | 36° 21' 48".30 | 33° 55' 52".45 | 110.62 | WGS84 | Bizans |
| 3 | 3 | Aphrodisias Antik Kenti | Yesilovacik | 56213 | 400323 | 56210 | 400163 | 36° 9' 26".85 | 33° 41 25".67 | 59.16 | WGS84 | Ion-Holmi Kolonis |
| 4 | 4 | Cambazli Kilisesi | Cambazli | 59248 | 404981 | 59244 | 404820 | 36° 34' 29".22 | 34° 1' 59".72 | 975.15 | WGS84 | Bizans |
| 5 | 5 | Karakabakli Antik Kenti | Karadedeli | 59110 | 403380 | 59106 | 403219 | 36° 25' 50".23 | 34° 0' 57".48 | 446.44 | WGS84 | Bizans |
| 6 | 6 | Kultesir | Karadedeli | 58913 | 403625 | 58910 | 403464 | 36° 27' 10".46 | 33° 59' 39".61 | 601.41 | WGS84 | Bizans |
| 7 | 7 | Isikkale Antik Kenti | Karadedeli | 59035 | 403480 | 59031 | 403319 | 36° 26' 22".92 | 34° 0' 27".79 | 508.43 | WGS84 | Bizans |
| 8 | 8 | Demircili Anit Mezar_1 | Demircili | 58597 | 403545 | 58594 | 403383 | 36° 26' 45".29 | 33° 57' 32".25 | 761.44 | WGS84 | Roma |
| 9 | 9 | Uzuncaburc (Diokaisereia) Antik Kenti | Uzuncaburc | 58285 | 405071 | 58281 | 404909 | 36° 35' 1".40 | 33°55'32".68 | 1246.19 | WGS84 | Helenistik |
| 10 | 10 | Olba Antik Kenti | Uzuncaburc | 58638 | 405081 | 58635 | 404919 | 36° 35' 3".42 | 33°57'54".97 | 1244.16 | WGS84 | Helenistik |
| 11 | 11 | Uc Guzeller Mozaigi | Narlikuyu | 59975 | 403358 | 59971 | 403196 | 36° 25' 39".90 | 34°6'44".74 | 59.39 | WGS84 | Roma |
| 12 | 12 | Tekir Ambari (Bizans Su Sarnici) | Pazarkasi | 58266 | 402761 | 58262 | 402599 | 36° 22' 32".03 | 33°55'16".19 | 94.60 | WGS84 | Bizans |
| 13 | 13 | Roma Koprusu | Saray | 58302 | 402800 | 58299 | 402639 | 36° 22' 44".82 | 33°55'30".90 | 69.59 | WGS84 | Roma |
| 14 | 14 | Roma Tapinagi | Saray | 58351 | 402764 | 58348 | 402603 | 36° 22' 32".92 | 33°55'50".58 | 80.59 | WGS84 | Roma |
| 15 | 15 | Silifke Kalesi | Pazarkasi | 58230 | 402766 | 58227 | 402605 | 36° 22' 34".05 | 33°55'2".05 | 205.60 | WGS84 | Olba |
| 16 | 16 | Tokmar Kalesi | Tokmar | 56925 | 401428 | 56922 | 401267 | 36° 15' 23".57 | 33°46'14".04 | 512.92 | WGS84 | Selcuklu |
| 17 | 17 | Mezgitkale | Ozturkmenli | 59206 | 403787 | 59203 | 403625 | 36° 28' 1".81 | 34°1'37".91 | 544.36 | WGS84 | Roma |
| 18 | 18 | Meydan Kalesi | Imamli | 58741 | 404101 | 58737 | 403939 | 36° 29' 45".24 | 33°58'32".24 | 848.33 | WGS84 | Roma |
| 19 | 19 | Gokburc | Ovacik | 59040 | 404238 | 59036 | 404076 | 36° 30' 28".74 | 34°0'32".94 | 978.29 | WGS84 | Bizans |
| 20 | 20 | Resadiye Camii | Saray | 58369 | 402773 | 58365 | 402612 | 36° 22' 35".82 | 33°55'57".56 | 79.59 | WGS84 | Osmanli |

(0 out of 46 Selected)

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Figure 3. Database table of Cultural Heritages

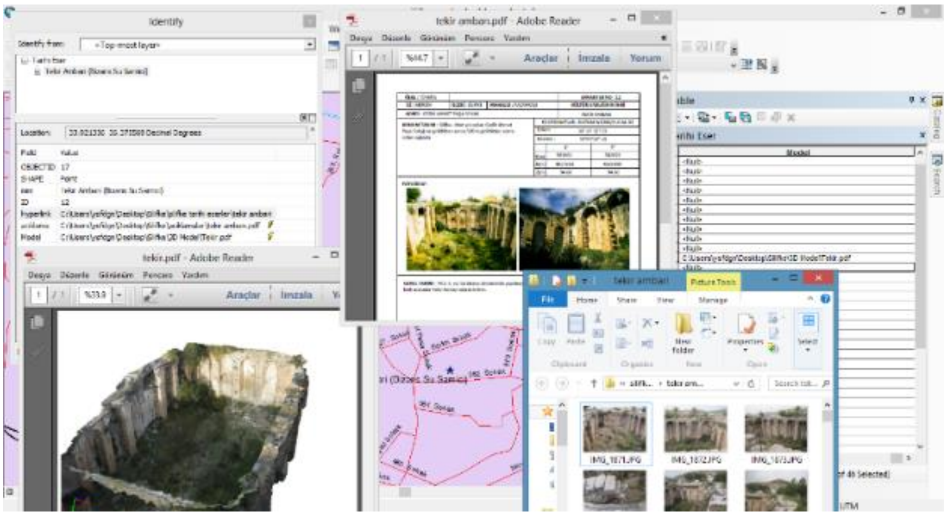

Figure 4. Calling data integrated with hyperlink

Once the whole system was designed, network analysis, query by feature, exporting of scale maps, and integration with hyperlink of documents such as photographs, inventory, and 3D models were completed.

Roman period cultural heritages have been detected, and network analyses have been created for those heritages (Figure 1, Figure 2, Figure 4, Figure 5).

## 2.3 Photogrammetric Works

Photogrammetric works were carried out in two places, field and office. The field step of the works aims to obtain structural data by photogrammetric methods. These data consist of surveying techniques based on geodetics and photographs taken by photogrammetric methods.

In this study we surveyed three monumental tombs in Silifke: Mezgitkale, Öterkale, and Korinth style Imbriogion monumental tombs. Polygon points were set up as closed traverses on different locations where each façade of the structures could be seen and were facing

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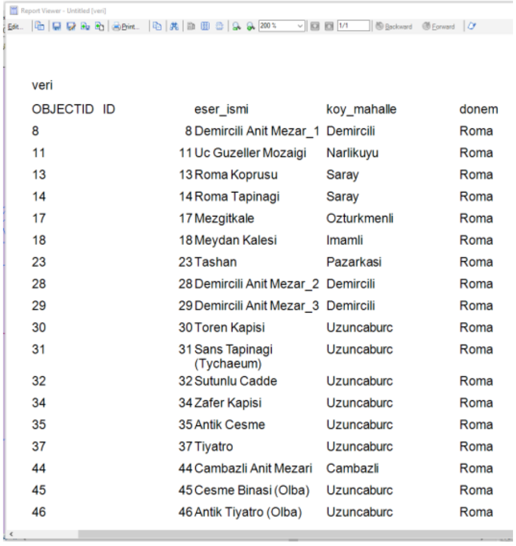

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| OBJECTID | ID | eser_ismi | koy_mahalle | donem |
|---|---|---|---|---|
| 8 | 8 | Demircili Anit Mezar_1 | Demircili | Roma |
| 11 | 11 | Uc Guzeller Mozaigi | Narlikuyu | Roma |
| 13 | 13 | Roma Koprusu | Saray | Roma |
| 14 | 14 | Roma Tapinagi | Saray | Roma |
| 17 | 17 | Mezgitkale | Ozturkmenli | Roma |
| 18 | 18 | Meydan Kalesi | Imamli | Roma |
| 23 | 23 | Tashan | Pazarkasi | Roma |
| 28 | 28 | Demircili Anit Mezar_2 | Demircili | Roma |
| 29 | 29 | Demircili Anit Mezar_3 | Demircili | Roma |
| 30 | 30 | Toren Kapisi | Uzuncaburc | Roma |
| 31 | 31 | Sans Tapinagi (Tychaeum) | Uzuncaburc | Roma |
| 32 | 32 | Sutunlu Cadde | Uzuncaburc | Roma |
| 34 | 34 | Zafer Kapisi | Uzuncaburc | Roma |
| 35 | 35 | Antik Cesme | Uzuncaburc | Roma |
| 37 | 37 | Tiyatro | Uzuncaburc | Roma |
| 44 | 44 | Cambazli Anit Mezari | Cambazli | Roma |
| 45 | 45 | Cesme Binasi (Olba) | Uzuncaburc | Roma |
| 46 | 46 | Antik Tiyatro (Olba) | Uzuncaburc | Roma |

Figure 5. Report for Roman CHs as a result of query

each other so that surveying of each side could be possible. Measurements were carried out by Total Station on every single point in the local coordinate system that we defined, and then point coordinates were calculated by closed-traverse calculation (Figure 6). The coordinates of about ten points on each façade were measured by using marker sheets taped onto the structure or to specific details on the wall of structure.

Care was taken to make the photographs overlap each other by taking plenty of photographs from all around the structure. High rates of photograph overlap are quite successful in generating more quality and detail in 3D models (Figure 7).

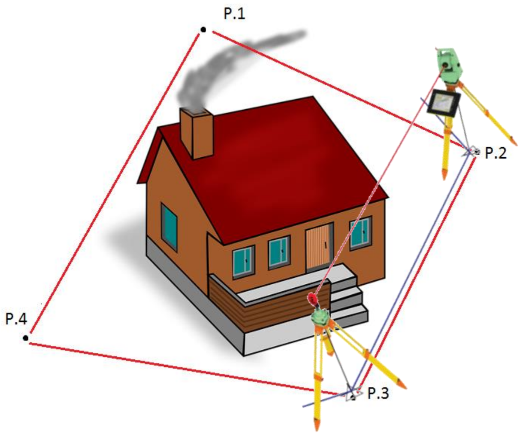


Figure 6. Setting up closed traverse

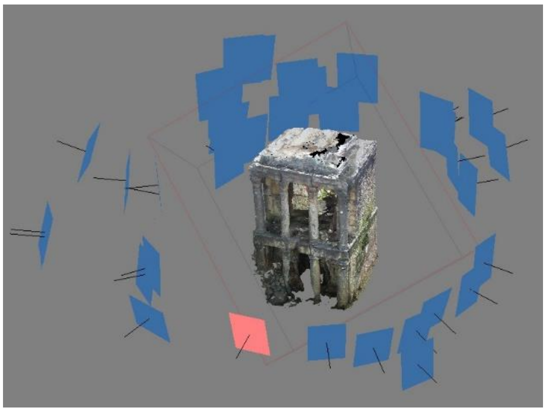

Figure 7. Positions of camera during data acquisition

The calibration of the Canon SX220 HS digital camera was accomplished by using PhotoModeler and several images of the calibration sheet supplied by the software. The photographs and the reference points acquired were imported into the software. Reference points were marked on the structures that were taped in the field works. Referenced photographs were oriented and adjusted to measure and to draw on the photographs (Figure 8). Three-dimensional wireframe models of the structures were generated by drawing corners and specific details on the photographs (Figure 9). 3D textured model were created by using wireframe that we created (Figure 10).

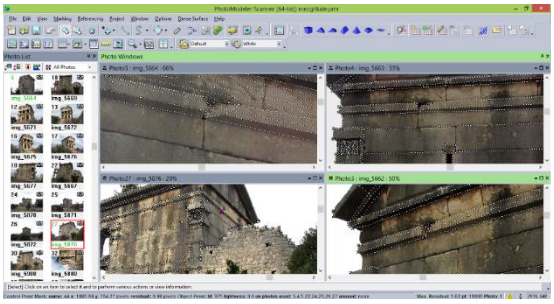

Figure 8. Drawing details from photographs

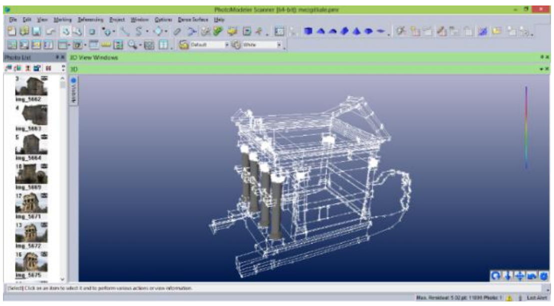

Figure 9. 3D wireframe model of Mezgitkale

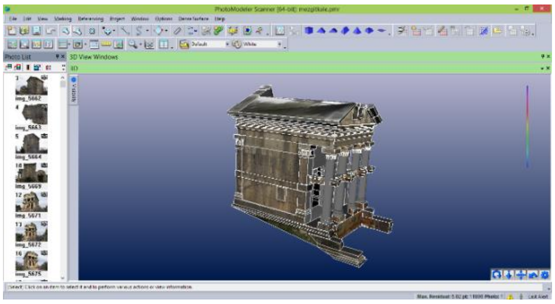

Figure 10. 3D textured model of Mezgitkale

The other photogrammetric software we used to generate 3D models is AgiSoft PhotoScan. This is software that generates point clouds from images. It has a quite usable interface and generates 3D models in several simple steps. The software also needs camera calibration, but pre-calibration is not necessary even though it is available to process the photographs, because camera calibration parameters can be solved when photographs are aligned in the first step. As a result of aligning photos, sparse point clouds were generated. Reference points acquired were marked on the aligned photographs, and the following steps were performed: building dense point clouds (Figure 11), adding mesh, and adding texture (Figure 12).

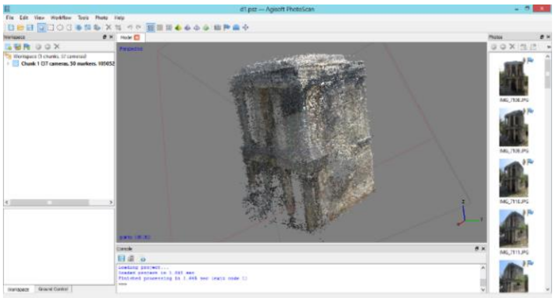

Figure 11. 3D point cloud of Öterkale Imbriogion

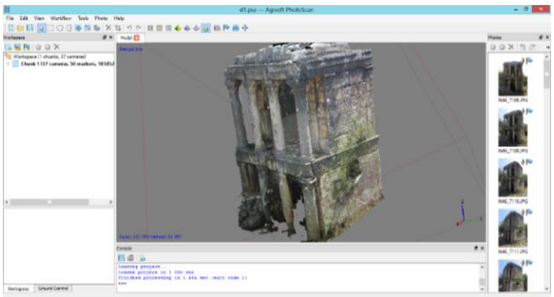

Figure 12. 3D textured model of Öterkale

A lot of data—images, coordinates, and information about 46 heritages—have been collected from the field and various sources. An inventory of all those heritages has been created by using the data acquired.

Generated 3D models have been exported in 3D PDF format from PhotoScan software, so it is available for all computers, including those in which the software is not installed (Figure13).

Inventory and exported 3D models have been integrated by using hyperlink in ArcGIS software. Therefore, it is available to present information, inventory and 3D models of cultural heritages (Figure 5).

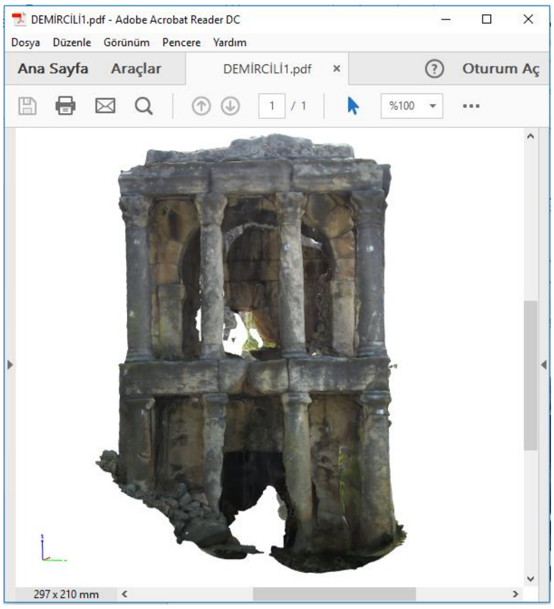


Figure 13. Exported 3D model in PDF format

## 3. CONCLUSION

The Geographic Information System is the most versatile tool for documenting, storing, and presenting cultural heritages. It is also a significant source for restoration and restitution works, as known restoration and restitution works require considerable costs. Deciders have to make the right decisions to manage their investments and to avoid prodigality. However, our fundamental aim is to protect the cultural heritages and to ensure their sustainability, but we are also thinking that we are bringing a strong base to state agencies and private companies as a result of this study. The system may facilitate and accelerate access to the information about cultural heritages so that important decisions could be made quickly and accurately. We believe that this system would benefit to every discipline, that is from tourism to architectural and, from economy to sociology.

Silifke is a city with a deep-rooted and rich history that has numerous cultural heritages such as theaters, aqueducts, fountains, royal and commercial roads, mausoleums, mints, castles, and others. Therefore, Silifke has been a very efficient workplace for us. The heritages have been documented and integrated into the information system, and a digital archive has been designed for quick access. Three-dimensional models have been generated with two different software methods but with the same survey techniques.

It is obvious that cultural heritage documentation is a requirement for their protection, and integration into GIS is a requirement to make accurate decisions for using the sources correctly. It plays a significant role in developing the country in a regular plan created by GIS.

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