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Research Article*

## **ANALYSIS OF THE UTILITY OF THE UNMANNED AERIAL VEHICLE(UAV) IN VOLUME CALCULATION BY USING PHOTOGRAMMETRIC TECHNIQUES**

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**ABSTRACT:** Together with developments in software technology, various interpolation methods allow terrain surfaces to be better identified. The accuracy rate in volume calculations is directly proportional with representation in the best form. The non-metric cameras, which are assembled to unmanned aerial vehicles (UAVs), provide convenience in the photogrammetric measurements. Sensitive images are obtained with less cost by the use of unmanned aerial vehicles.

The purpose of this study was to take photos from the air with the help of UAVs and to make volume calculations by using photogrammetric techniques. At the end of the study, the photogrammetric method had been completed in a shorter period than with the traditional method. The values found as the result of both methods have been found to be compatible with each other in the ratio of 99.33% in terms of sensitivity.

**Keywords:** UAV, UAV photogrammetry, volume calculation

## 1. INTRODUCTION

UAV technology represents feasible instrumentation for places or projects that would require periodic measurement of volume calculations, such as large construction sites, mines with excavations and fillings, or coal dumping areas. It is, of course, possible to make such volume calculations by classical geodetic methods; however, regarding time management, economics, and precision, deploying UAVs would be a more optimum solution. It is not possible to re-measure the previously measured spots in areas measured by classical methods at the same positions and at the necessary frequency, so triangulation of the previously constructed digital land models and the later-constructed digital land models would not be possible. Therefore precise volume calculations cannot be performed.

In general, the volume of earth to be excavated and filled needs to be calculated in the land-related works of engineering projects (roads, construction, mining, etc.).

Volume calculations are usually performed by using cross sections, prisms, surface-leveling measures, and contour maps (Yakar et al., 2009).

The most prominent techniques to prepare Digital Elevation Models are photogrammetric methods with stereo data (Hohle, 2009; Kraus, 2007; Akar, 2017).

Generally, classical methods have been used in volume computing. The trapezoidal method (rectangular or triangular prisms), classical cross-sectioning (trapezoidal, Simpson, and average formula), and improved methods (Simpson-based, cubic spline, and cubic Hermite formula) have been presented in the literature (Yanalak, 2005). Efficient volume computation at high accuracy is an important question, both theoretically and practically (Soole and Poropat, 2000).

Also, in modern times, land surfaces are better defined by using various interpolation methods with the recent developments in software technologies. Also, accuracy in volume calculations is correlated with how well the land surface is represented. The best representation of land surface depends on the density and distribution of spots with known coordinates at the land surface and on the interpolation method applied. Undoubtedly, more spots with appropriate distribution would enable better representation of the land surface. However, more spots would mean more time and more cost. In some cases, producing spots geodetically can be risky and even impossible. Accordingly, land surfaces cannot be represented at the desired precision (Yilmaz and Yakar, 2007).

## 2. UNMANNED AERIAL VEHICLE (UAV) PHOTOGRAMMETRY

Imaging of terrestrial surfaces by cameras mounted on unmanned aerial vehicles (UAV) has presented certain advantages over geodetic measurement techniques. Very-high-resolution spatial and temporal images can be obtained by deploying unmanned aerial vehicles. Such high-resolution images can be used for various purposes (Yilmaz et al., 2013).

The use of UAVs has become a recently adopted method in acquiring needed spatial data. A UAV is a vehicle that can move, automatically or semi-automatically, within a flight plan or can be flown through remote control by a pilot on land or in another vehicle. UAV systems can be an alternative for piloted mapping systems, which pose low resolution and high cost constraints due to high-altitude flight necessities. UAV-based data gathering and mapping can provide the precision needed for works in many areas, such as agriculture, forestry, urban planning, and disaster management (Döner et al., 2014). UAV photogrammetry (Eisenbeiss, 2008c) defines a photogrammetric measurement platform that operates by remote control, semi-independently or fully independently, lacking a pilot seated in the vehicle. The platform is equipped with photogrammetric measurement systems, including a smaller mid-sized immobile video camera, thermal or infrared camera systems, and LIDAR systems. With a standard UAV, it is possible to monitor recording, location, and direction of the applied sensors in a local or general coordinate system.

Recently, several private companies have offered photogrammetric products produced by means of UAV-based imagery for certain applications; mainly these are DSMs and orthoimages. Furthermore, monitoring or change detection often plays a role—detection of new buildings and changes at forest areas, gravel pits, or waste sites have so far been identified as potential applications. Further and more specific applications can be found in the scientific literature (Eisenbeiss et al., 2005; Lambers et al., 2007; Reidelstuerz et al., 2007; Grenzdörffer et al., 2008; Eisenbeiss, 2009; Niethammer et al., 2009; Vogler et al., 2009; Sauerbier et al., 2011).

## 3. STUDY AREA

This application was carried out on the Alaaddin Keykubat Campus, Seljuk University. The dimensions of our application area were 20 m x 18 m x 3 m (L x W x H) (Figure 1).



Figure 1. General appearance of application area of volume calculation of the Alaaddin Keykubat Campus, Selcuk University

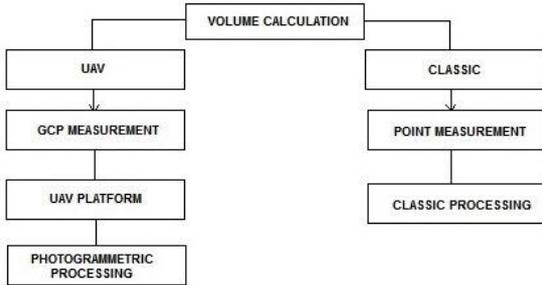


Figure 2. Flowchart of the applied methodology

The workflow of this application consists of preparation before study, field work, and office work.

### 3.1 Preparation before Study

The following were supplied for the study: UAV (Unmanned Air Vehicle) used in the application (Figure 2), camera (Figure 3), image transmission system (Figure 4), total station (Figure 5), and ground control markers (used in evaluating the photographs obtained from the UAV) (Figure 6).



Figure 2. Octocopter UAV



Figure 3. Canon PowerShot A810 Serisi Dijital Kamera



Figure 4. FatShark image transfer system(URL-1)



Figure 5. Topcon GPT – 3007 Reflectorless Total

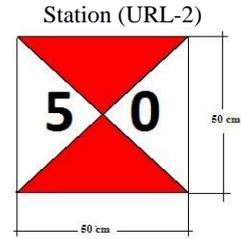


Figure 6. Close view of ground control point, used in the photographs taken from air

### 3.2 Field Work

First of all, our ground control points were homogeneously installed in the application area (Figure 7). For our application, eight ground control points were installed. Care was taken in installing the ground control points so that the distribution of the points was such that they completely covered the work area and that they could “see each other”.

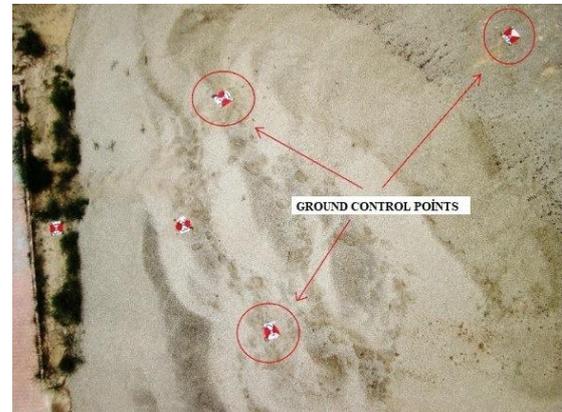


Figure 7. Ground control points used in the photographs taken from air

Coordinating the processing of ground control points was carried out by means of a Topcon GPT 8203A total station without a reflector. The coordinates of the ground control points were calculated by installing a closed polygonal route on the periphery of the application area. Besides this, 1415 detail points were measured with intervals of about 40 cm to calculate the volume via the classical method. The coordinates of ground control and detail points were evaluated in the local system.



Figure 8. Coordinating and detail measurement process

After these processes, the stage of taking photos proceeded (Figure 9). The process of taking photos was integrated to the Octocopter UAV system, and the process was carried out by the Canon A810 digital camera (Figure 3). Thanks to the telemetric system that is present in the UAV, some information, such as flight altitude and horizontal and vertical velocity, were read, and, thanks to the GPS mode of the UAV, the process of taking photos was realized, on average, from 20 meters altitude.



Figure 9. Process of taking air photographs with the UAV

In the application, through the camera carried in the UAV, 85 photos were taken, and 24 of those photos were used in the process of photogrammetric assessment.



(a)



(b)

Figure 10. Two examples of photos taken by means of UAV for photogrammetric assessment

After these processes were completed by means of the data obtained, they were passed on to office work.

### 3.3 Office Work (Data Processing)

In this stage, the coordinates of the ground control points obtained from the field were initially displayed in the Netcad software by means of the total station device.

The coordinates of the ground control points were arranged in the format supported by Photomodeler software and recorded as “.txt”.

Further, among photographs taken with the UAV, those to be used in the assessment of the photos in the “text” format were transferred to Photomodeler software, and the internal directing parameters of camera (its calibration values) were entered (Figure 11).

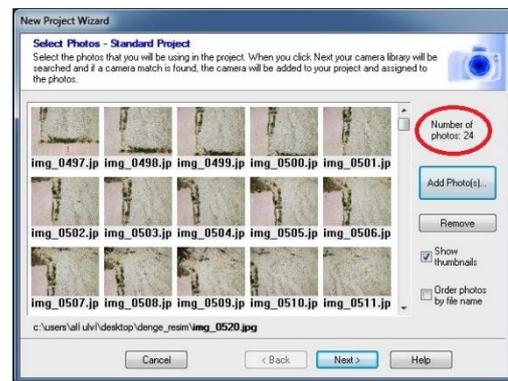


Figure 11. Transfer of photographs obtained from UAV to the Photomodeler software

After the photographs were transferred, by means of the “Smart Points Project” module in the Photomodeler software, the photographs were automatically directed and balanced to each other. As a result of that process, 24 photographs of the application area obtained from the UAV were balanced.

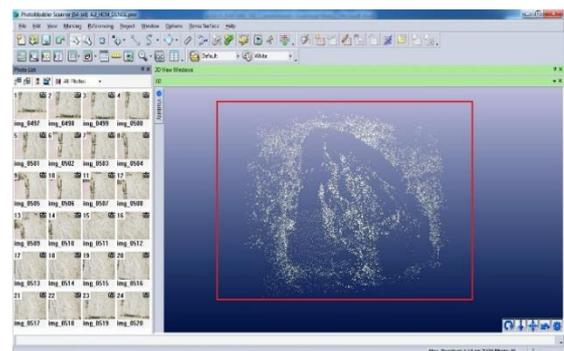


Figure 12. Automatically identified reference points on the photographs in Photomodeler software

After those processes, ground control points that were present on the different photographs in the Photomodeler software were matched by removing points (Figure 13).

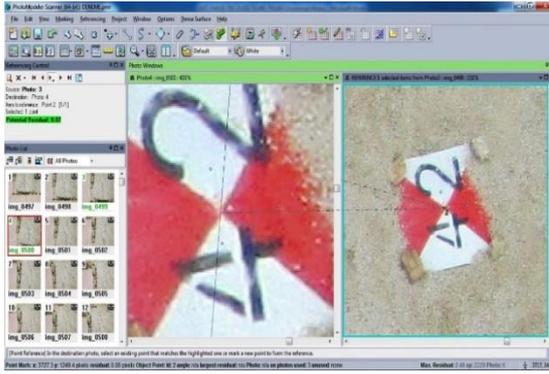


Figure 13. Matching ground control points from the different photographs in Photomodeler software

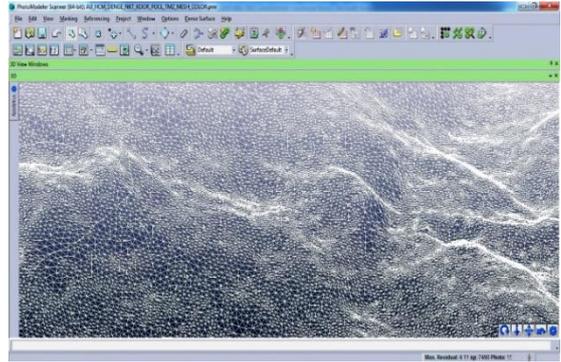


Figure 16. Triangle model formed by point cloud

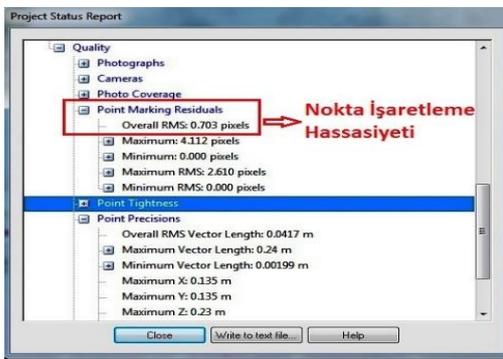


Figure 14. Balancing report in Photomodeler software

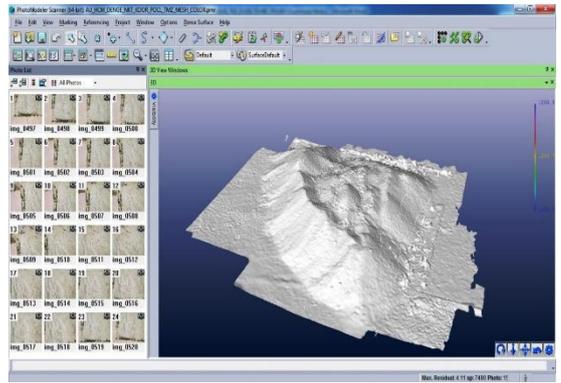


Figure 17. Solid model

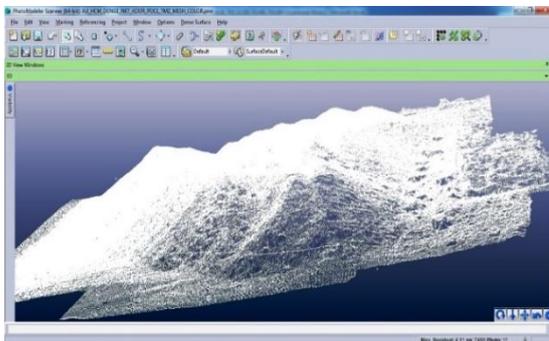


Figure 15. Point cloud of sand pile

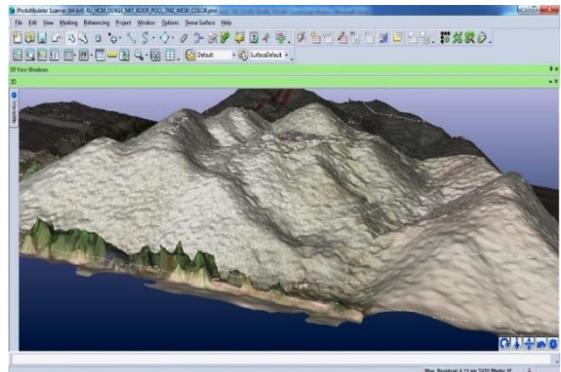


Figure 18. Texture-covered state of solid model (SAM)

After those processes had been completed, a triangle model was obtained from the point cloud that was present on the area and whose volume would be calculated. A solid model and a SAM were also produced from this model (Figures 17–18). Contour lines were passed through the triangle at 20-cm intervals, and a contour map was produced (Figure 19).

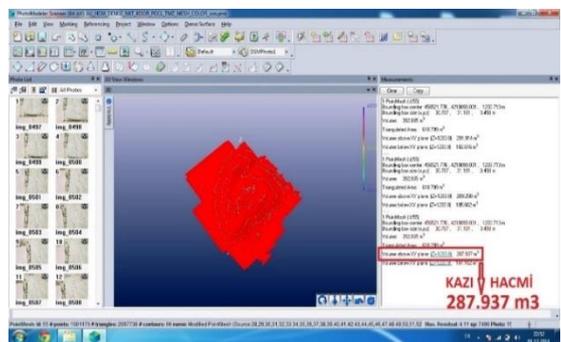


Figure 19. Result of volume calculation in Photomodeler software

After calculation of volume made by means of the UAV by using photogrammetric techniques through Nectad software, volume was calculated by the classical method. For that calculation, 1415 detail points, measured in the field, were used, and base code was calculated as 1213 m (Figures 21–22).

To enable a more valid comparison, control points used in the volume calculation made by means of the UAV and photogrammetric techniques were used in the calculation of volume by the classical method.

Because of that, the differences that may have been formed between the border whose volume would be calculated by the classical method and the border whose volume would be calculated by photogrammetric techniques were impeded.

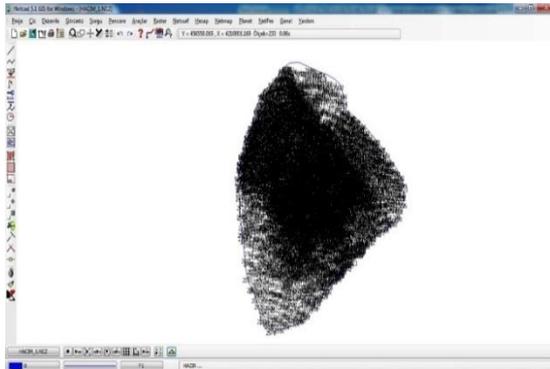


Figure 22. Displaying the detail points in Nectad software

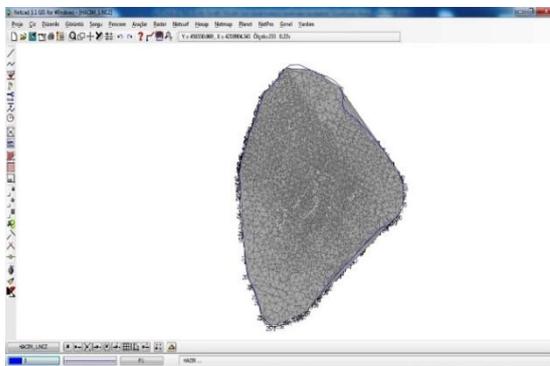


Figure 21. Triangle model formed in Nectad software

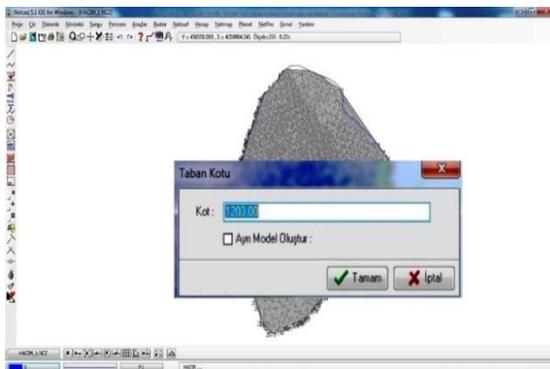


Figure 22. Identification of base code in Nectad software

After those processes,, a volume calculation was made by passing a common line through the triangle mode formed in the Nectad software for one time in each 25 cm (Figure 23).

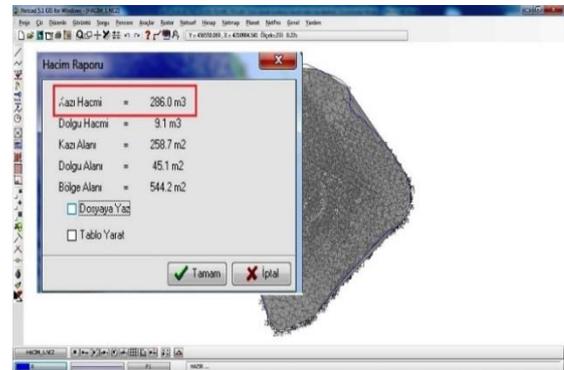


Figure 23. Result of unit calculations in Nectad software

#### 4. RESULTS

Two different methods, photogrammetric and classic calculation, have been compared in the volume calculation. The comparison considered both duration and precision. The duration of total work of photogrammetric volume calculation was 60 minutes on a 360-m<sup>2</sup> area, while it was 220 minutes for the classical volume calculation (Table 1).

Table 1. Comparison of photogrammetric and classic volume calculation techniques

JAV STUDY	CLASSIC STUDY	TIME (Minutes)	
		UAV	CLASSIC
GCP Measurement	Point Measurement	10	180
Take photo with UAV	-	10	-
Photogrammetric Processing	Classic Processing	35	35
Volume Calculation	Volume Calculation	5	5
<b>TOTAL</b>		<b>60</b>	<b>220</b>

Volume calculation by UAV was completed in one fourth the time required for the classical calculation, enabling time savings and thus financial savings. The values of volume calculation produced by using photogrammetric techniques were compared with the classical method and UAV (Table 2).

In comparing these values, the volume calculation determined by the classical method was accepted as the exact value.

Table 2. Results of accuracy research of the volume calculation, made by means of UAV by using photogrammetric techniques

PARAMETERS	VALUES			
	CLASSIC (m <sup>3</sup> )	UAV PHOTOGRAMMETRY (m <sup>3</sup> )	DIFFERENCES (m <sup>3</sup> )	ACCURACY RATE %
SOLID VOLUME (m <sup>3</sup> )	286	287.94	-1.94	99.33
REFERENCE Code (m)	1203	1203	0	-----

In the light of these data, the volume calculation made by means of the UAV, using photogrammetric techniques, compared to the volume calculation made by the classical methods, were calculated with a difference of 1.94 m<sup>3</sup> (table 1). Accuracy analysis shows that the volume calculation made by means of the UAV using photogrammetric techniques were in 99.33% agreement with the volume calculation made by means of the classical method, and it was seen that sufficient accuracy was provided. Also, when the advantages it provided in terms of the concepts of cost and time are considered, it is a clear reality that volume calculation by the classical method will be replaced by UAV and photogrammetric techniques. Besides those results, it should not be ignored that SAM was obtained in addition to volume calculation. Because of that, data can be used more realistically and accurately. SAM, produced in Photomodeler software, can be printed in various formats from the software.

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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.

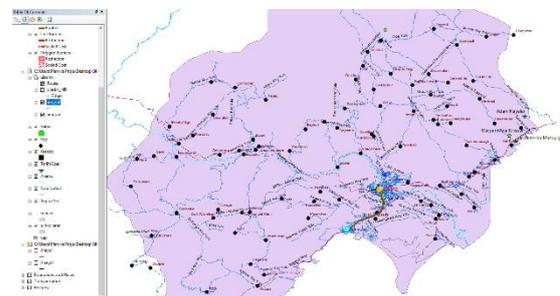


Figure 1. Digitized boundary, roads, streams, and settlements

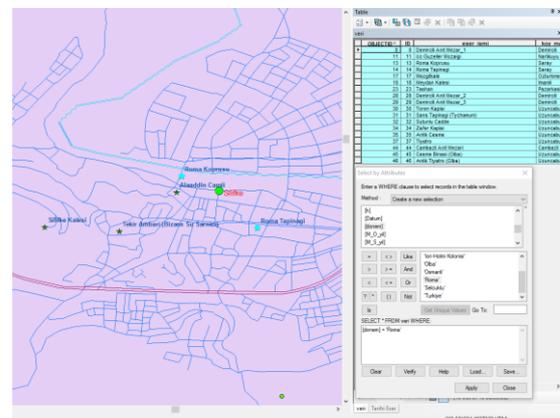


Figure 2. Query of Roman period cultural heritages by using Select by Attributes menu

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

each other to pull the data together in meaningful ways.

QR	ID	eser ismi	koy mahalle	Y 3	X 3	Y 6	X 6	phi	lamda	h	Datum	donem
1	1	Meryem Ana Kilisesi	Narıkuyu	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	Isikale Antik Kenti	Karadedeli	59035	403480	59031	403319	36° 26' 22".92	34° 0' 27".79	508.43	WGS84	Bizans
8	8	Demircilli Anit Mezar_1	Demircilli	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	Narıkuyu	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

Figure 3. Database table of Cultural Heritages

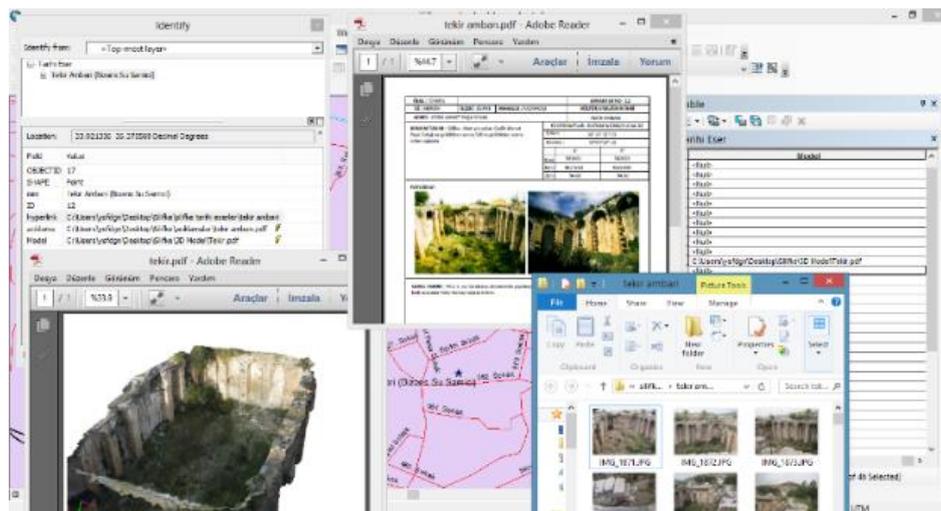


Figure 4. Calling data integrated with hyperlink

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

OBJECTID	ID	eser_ismi	koy_mahalle	donem
8		8 Demircilli Anit Mezar_1	Demircilli	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 Demircilli Anit Mezar_2	Demircilli	Roma
29		29 Demircilli Anit Mezar_3	Demircilli	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).

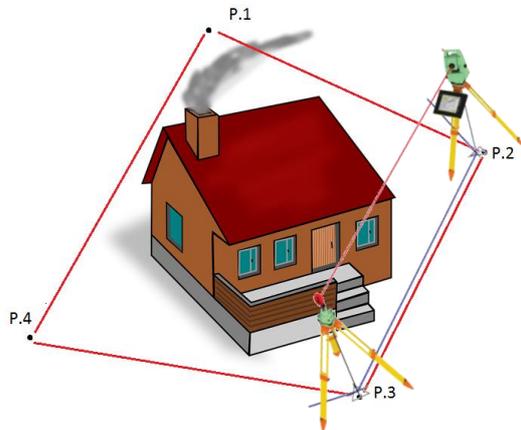


Figure 6. Setting up closed traverse

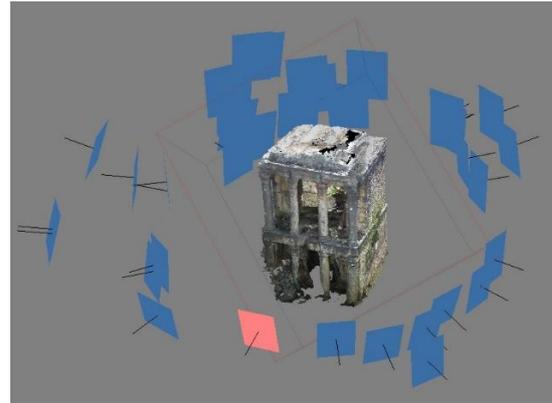


Figure 7. Positions of camera during data acquisition

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).

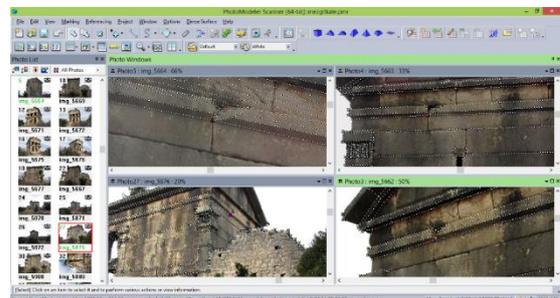


Figure 8. Drawing details from photographs

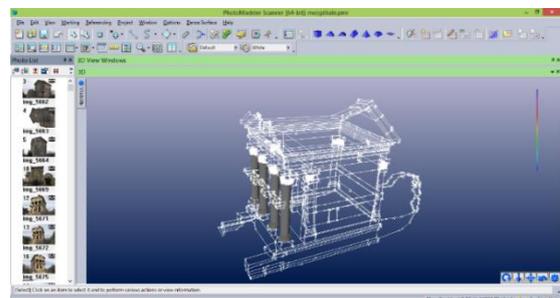


Figure 9. 3D wireframe model of Mezgitkale

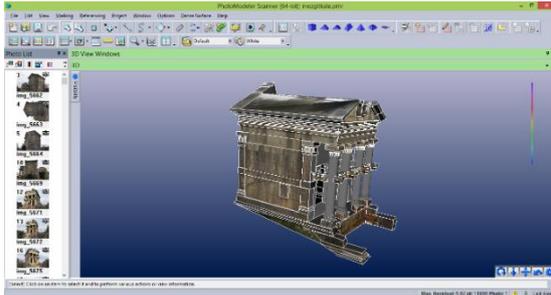


Figure 10. 3D textured model of Mezgitkale

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).

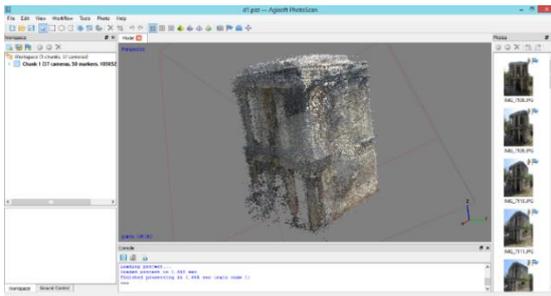


Figure 11. 3D point cloud of Öterkale Imbriogion

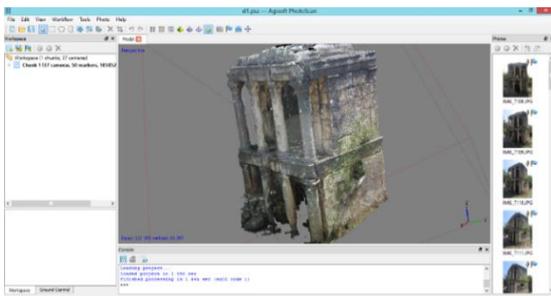


Figure 12. 3D textured model of Öterkale

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).

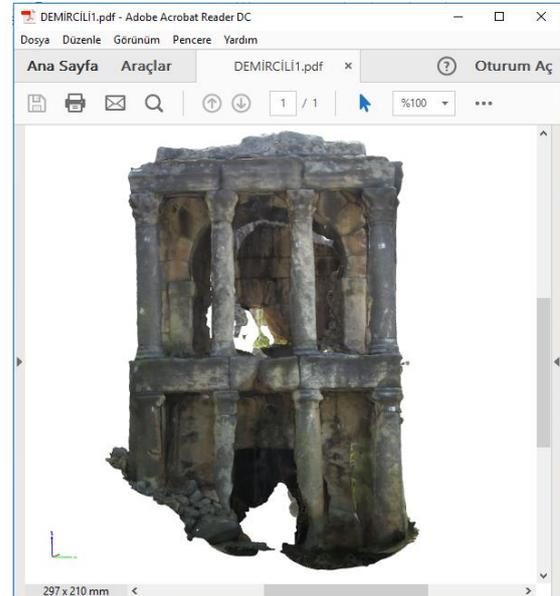


Figure 13. Exported 3D model in PDF format

### 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.

#### ACKNOWLEDGEMENTS

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DOI: 10.26833/ijeg.380752  
Research Article*

## **DETERMINATION OF BUILDING MATERIALS WITH IR-THERMOGRAPHY IN HISTORICAL BUILDINGS**

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**ABSTRACT:** Lately, IR thermography is frequently applied for important purposes in monitoring buildings such as energy leaking, ventilating and air-conditioning installations, electrical and mechanical installations, moisture detection etc. Nondestructive monitoring methods are essential in case of monitoring historical buildings. It is curtail not to destruct any part of the buildings, which are historically important. Therefore, nondestructive methods need to be used while monitoring this kind of buildings. In this study, IR-Thermography was used in order to distinguish different construction materials that were used to build the walls of a historical building. The thermal monitoring was made with Optris PI-450 long wave infrared camera. The results showed that IR monitoring can be useful to distinguish the building materials without destroying the investigated buildings' plaster or facing. It is observed that the best results can be achieved on higher temperatures at IR-Thermography.

**Keywords:** *Remote Sensing, Building Materials, IR-thermography, Historical Buildings.*

## 1. INTRODUCTION

The role of remote sensing for historical structures is becoming more and more crucial role in the documentation and restoration process. Many papers can be found on this topic using different remote sensing instruments such as lidar technology (Raimondi, Weibring et al. 1998), unmanned aerial vehicle (Ulvi and Toprak 2016), thermal imaging, etc. Although the infrared light was discovered by William Hershel around 1800, the first imaging instruments were built in the late 1940s and 1950s, built for the American military for night vision (Kaplan 2007). All matter radiates energy at thermal IR wavelengths (3 to 15  $\mu\text{m}$ ) both day and night. The ability to detect and record this thermal radiation as images have obvious reconnaissance application. Thermal IR images generally record broad spectral bands, typically 8.0 to 14.0  $\mu\text{m}$  for images from satellites (Sabins 2007). The thermal camera technology can be used as a nondestructive diagnostic technique used in different applications (Malone, Celeste et al. 2005, Pascucci, Bassani et al. 2008). The advantage of thermal imagery to detect the temperature can be of great use in many application and study areas. It is being widely used in the monitoring of animals (Jerem, Herborn et al. 2015, Zheng, Zhu et al. 2016), agriculture (Vadivambal and Jayas 2011), industrial applications, gas detection (Lewis, Yuen et al. 2003), fire detection and military, detection and tracking of humans (Ma, Wu et al. 2016), medical analysis (Jones 1998, Jones and Plassmann 2002), building inspection, and etc. Thermal cameras have been used for years for inspecting heat loss from buildings (Gade and Moeslund 2014). Besides heat loss detection, thermal imaging has been used to detect problems behind the surface and for some ancient buildings, it is of interest to monitor wall's hidden structure that can be done with thermal camera (Grinzato, Bison et al. 2002). The building inspection monitoring has to be conducted with nondestructive methods in historical buildings.

In this paper, an attempt for material classification and material characterization of a historical building has been made. The exterior walls of the building were considered/presumed to be made of stone. The camera used in this paper, Optris PI-450 has a spectral range from 7.5 to 13.5  $\mu\text{m}$ , temperature range -20 to 900  $^{\circ}\text{C}$ / 200 to 1500  $^{\circ}\text{C}$ , and typical applications, real-time thermographic images in high speed and detection of smallest temperature differences (OptrisInfraredThermometers).

IR thermal monitoring, as a nondestructive monitoring method, especially for historical building it is of great importance. The main purpose of this study was to observe the inner walls of the building. For this purpose, thermal imaging method was used. Within the scope of the study also the exterior walls were observed of The Republic Historical Museum in Eskisehir Turkey in property of Anadolu University and since the results did not fit with the observation discussed in (Nalçakan 1995), the exterior walls also required attention, and the measurements and result are discussed in this paper. The results were compared with building with similar characteristics. Afterwards, an unsupervised classification of the thermal images has been made in order to separate the materials. The results from this

study were found to be very useful for the construction work planned in the museum.

## 2. STUDY AREA

The building studied in this paper, The Republic Historical Museum in Eskisehir Turkey is located in the historical part of Eskisehir, Odunpazari in Turkey. The building has been opened in 1916 and it was first used as a school (Nalçakan 1995). From 1916 until today, it has been used for different purposes. After long years it has been also used as a Directorate of Public Works, Treasury, and girls High School. In 1955, the Ministry of National Defense gave the building for use to the Regional Command and after it was used as a Military Service Branch. In 1980 it was registered as Ancient Artifact. After not being used for a long period, in 1989 the building has been given to Anadolu University to be used as a Republic Historical Museum (Nalçakan 1995). After restoration, the museum has been open for a visit since 23 April 1994 ([www.anadolu.edu.tr](http://www.anadolu.edu.tr) 2016). Nowadays, the museum is closed due to maintenance.

The building has a basement, ground floor, and first floor, making a three-floors construction. The height of the basement is 3 meters, the ground floor 4.70 meters, and the first floor 4.50 meters. The buildings' first structural system was masonry. The external walls were made of cut stone, the interior walls were lath-and-plaster, slabs, stairs, ceiling, and doors were timber work and the entrance part of the building was floor arch (Nalçakan 1995). Later in the years' unknown reconstruction has been made and most of the materials used in the building remained unknown until today (Figure 1).



Figure 1. Republic Historical Museum – Eskisehir (source: <https://www.anadolu.edu.tr/kampuste-yasam/muze-ve-sanat-merkezleri/cumhuriyet-muzesi>)

## 3. METHODS

It is not possible and feasible to remove plaster in historical buildings, except in certain special circumstances. For this purpose, thermal imaging was done at different temperatures inside and outside the museum and at different dates. Optris PI 450 thermal imager was used for measurements made during the study (Figure 2). The temperature range of the camera is between -20 $^{\circ}\text{C}$  and 1500 $^{\circ}\text{C}$  and the optical resolution is 382x288 pixels (OptrisInfraredThermometers). Once measurements were made, Optris PI Connect software was used to analyze the images. The building was monitored every month from January until May in order to investigate the influences of different weather

conditions. Inside the museum, observations were made in January; it has been seen that it is difficult to distinguish different building materials such as concrete and stone because of the cold environment.



When the building materials were heated with heaters, the differences between the materials in the

Figure 2. Visible and thermal image of the same scene of the inspected building

images became clear. Since the air temperature is higher in May, the heater was not used because it was possible to observe the difference between the materials. During the monitoring with the thermal camera, the temperature inside and outside of the building was measured. Of the different thermal conductivity of the brick, stone and concrete materials, they were distinguished very clearly by the IR thermography method. In thermal records, interior walls' material was slightly different from surrounding concrete frame as seen in Figure 3.

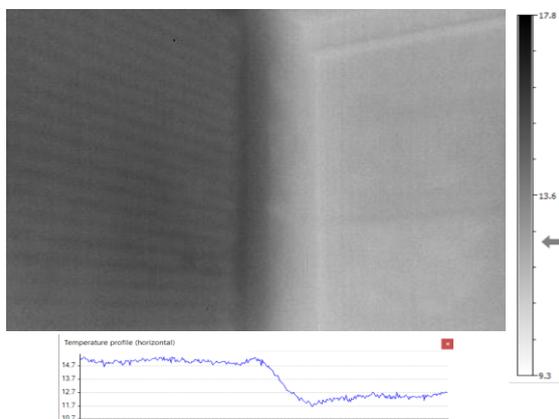


Figure 3. Thermal difference between the interior brick wall (left) and exterior stone wall (right).

The interior walls were observed with a thermal camera and the wall material was predicted to be brick due to the formation of the blocks and pointing stuff. For confirmation of the prediction, plaster was removed on several walls and it was seen that the inner walls have been constructed with brick blocks.

The exterior walls were observed from the inside and from the outside, according to records related to the building (Nalçakan 1995), the exterior walls were known as cut stone walls. Through thermal imaging, it was determined that these walls were built not only by stone walls but also by traditional brick-beamed stone wall type (brick beams are embedded in the stone wall to strengthen it). This information was confirmed by locally removing plaster on certain places (Figure 4).

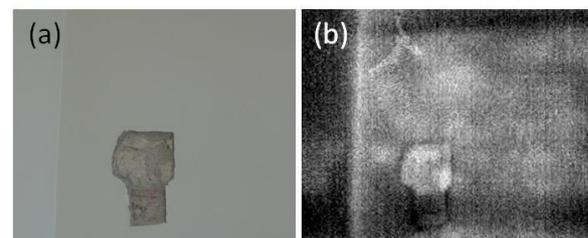


Figure 4. Thermal difference between brick and stone; a) Visible and b) thermal image of the same scene

As an additional control, only 50-meter distance of the Historical Museum, a building – Tiryakizade mosque with the similar building characteristics (stone wall with hacking – traditional Turkish style of construction) was observed and the results were compared.

Unsupervised classification using K-means method with four classes was used for separating the materials, mainly stone and brick from each other.

#### 4. RESULTS AND DISCUSSION

In the study, it has been investigated whether it is possible to use thermal camera images to determine wall materials without plaster or coating removal. At the end of the study, thermal imaging showed that the best results at higher temperatures. The use of the heater in the measurements that were made in the building at low temperatures affects the results positively.

According to the results of the made observations, different materials were seen to have different temperatures despite thick plaster layer. As the exterior walls were observed from the inside and from the outside, different building materials can be seen clearly in the façades that are warmed by the sun (Figure 5).



Figure 5. Visible and thermal images from the exterior walls observed from inside the building

The brick temperature was found to be about 1° C colder than the concrete. The temperature of the stone was determined to be around 24.5° C, or 2° C colder than the brick. In the inspections made from inside it was seen that the concrete is the warmest and the stone is the coldest. The thermography method has shown that the locations of different building materials such as stone, brick, concrete can be determined without damaging historical buildings. The results from the exterior walls measured from outside show more clearly the differences of the materials (Figure 6).

The results from the observation made on the exterior walls on the mosque showed the same difference between Figure 6. Temperature difference between concrete, stone and brick

The stone and the bricks of 2°C which shows that the plaster does not affect the observation made over the museum.

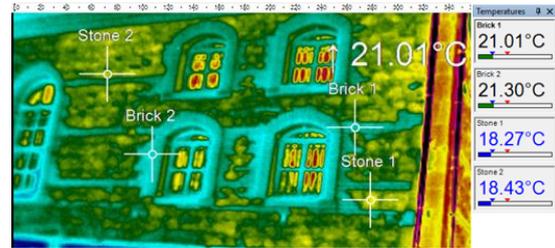


Figure 7. Tiryakizade Mosque Thermal Observations

After observing the results from the measurements it has been concluded that exterior wall has been made in a Turkish traditional ` brick-beamed stone wall ` style as seen in Figure 6 and 7. The results from this study are important for the observed building since until now it assumed that the external walls were made only from stone.

The result from the unsupervised classification were helpful in determining the stone and brick area. The classification was made according to the observed temperature. The results from the unsupervised classification are presented in Figure 7.



Figure 8. Results from the classification

The results obtained in the study demonstrates that the thermography method gives good results in determining building material differences without destroying plaster-covered surfaces. These results reveal that the thermography method is a useful method for the preservation and documentation of our historical and cultural assets.

The results from this study are important for the observed building since until now it assumed that the external walls were made only from stone.

## 5. CONCLUSION

It was concluded that thermal camera can be used for monitoring historical buildings without destroying the building. In this paper, the results showed that the interior walls of the building were made out of brick. Also, the results showed that the exterior walls of the building were made not only from masonry stone as it was considered, but also from bricks constructed in a Turkish traditional style.

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Research Article*

## **COMPARISON OF REGIONAL AND GLOBAL TEC VALUES: TURKEY MODEL**

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**ABSTRACT:** The ionosphere is a layer of atmosphere 60 km to 1100 km above the earth and is composed of solar rays and ionized gases. The ionosphere is an important layer affecting Global Navigation Satellite System (GNSS) measures. The quality of GNSS measures is directly related to the changes in the ionosphere. For this reason, monitoring changes in the ionosphere is quite important. One of the important parameters expressing the characteristic of the ionosphere is the Total Electron Content (TEC), which is a function of electron density exhibiting transformation with solar radiation.

In this study, 68 stations including 56 Continuously Operating Reference Stations-Turkey (CORS-TR) stations and also IGS stations were taken for evaluation. Bernese v5.2 GNSS software developed by Bern University of Switzerland was employed at the evaluation stage. From 2009 until 2015, TEC values were calculated at two hourly intervals, one day for each month. In the study, where a Single Layer Model was used, TEC values obtained from GNSS measurements have been compared with the TEC (IRI-2012 TEC) values obtained from the global ionosphere map (GIM-TEC) and the international ionosphere reference model programme published by the Centre for Orbit Determination in Europe (CODE), the European Space Agency (ESA), and the Jet Propulsion Laboratory (JPL). As a result, the regional (RIM) TEC values and the global (CODE, ESA, JPL) TEC values showed a large similarity, and the IRI obtained TEC values remained lower than these four values was observed. Correlation coefficient was calculated to determine the relationship between regional TEC values obtained after the evaluation and global TEC values. There is a positive and quite high correlation between the regional (RIM) TEC values produced by the calculated correlation coefficients and the global (CODE, ESA, JPL) TEC and IRI TEC values.

**Keywords:** GNSS, Total Electron Content (TEC), Ionosphere, Global Ionosphere Map (GIM)

## 1. INTRODUCTION

With respect to the signal propagation, the atmosphere is subdivided into two main layers of the troposphere (also referred to as neutral atmosphere) and ionosphere (Memarzadeh, 2009). The troposphere has refraction effect and causes similar effects on both code and phase modulation and results in a delay of up to 30 meters for a horizontal path. Therefore, the effect of the troposphere is considered one of the major sources of errors imposed on the satellite signals. On the other hand, the ionosphere having a dispersing effect among ionized atmosphere layer(s) affects the signal code and phase modulation in an opposing way (Başpınar, 2012; Basciftci et al, 2017b). The troposphere usually covers a region being up to 40 km from the sea surface, and the ionosphere covers about 60 km to 1000 km and even more.

Monitoring the ionosphere is important for mainly GNSS (Global Navigation Satellite System) and for study areas like communication, security, navigation as well. Changes in ionosphere effect satellite based studies directly. GNSS receivers are widely used in studies related ionosphere because they spread most of the world and the information (Total Electron Content, TEC) about ionosphere can be obtained from satellites monitored by these receivers. (Alçay et al., 2014).

The purpose of this study is to determine TEC values by benefiting IGS stations which have uninterrupted data between the years 2009-2015 were determined by using the data evenly distributed CORS-TR stations in order to modelling ionosphere in high sensitivity and resolution in Turkey, comparing the regional TEC values with global TEC values, determining the correlation coefficients to find out the relationship between regional TEC values with global TEC values. In this scope Bernese v5.2 GNSS software was used to determine the regional TEC values.

## 2. IONOSPHERE

Total Electron Content (TEC) used in expressing the general behaviour and structure of the ionosphere can be determined by GNSS. When it is thought that GNSS satellites are 20200 km above the earth, the signal sent from a satellite completely passes through the ionosphere layer and gives an advantage in understanding the structure of the entire ionosphere. Another advantage is that GNSS satellites make it possible to constantly monitor the ionosphere by transmitting uninterrupted signals (Inyurt, 2015).

The ionosphere is contained within a region between 60 km to 1100 km from Earth. This layer is the ionized part of the atmosphere and consists of free electrons and positively charged ions. The electrical properties of signal propagation and the environment are influenced by these particles (Hugentobler et al., 2001, Hunsucker and Hargreaves, 2003).

The ionosphere layer can be thought of as that part of the world between the neutral atmosphere and the atmosphere completely ionized by the Sun. In the neutral layer, while the wave propagation in the

ionosphere is being affected by the number of electrons available in the form of free electrons along the path of a wave, the propagation of waves in the ionosphere mainly depends on factors such as pressure, temperature and water vapour content. A large number of free electrons and ions emerge as a result of radiation from the Sun which hits molecules and atoms in the air. In fact, what determines the maximum and minimum height of the ionosphere layer is this ionization. The amount of electrons within a 1 m<sup>2</sup> based cylinder along the line between the receiver and the electromagnetic signal is called TEC (Total Electron Content) and is expressed in TECU units. 1 TECU = 10<sup>16</sup> electron / m<sup>2</sup> (Schaer 1999; Abdullah et al, 2009; Dach et al, 2015; Basciftci et al, 2017a). The single layer model (SLM) is an approach used to model the total electron density. This model assumes that all free electrons are compressed into a very thin layer at H height above the Earth's surface (Wild, 1994). TEC varies according to the time of day, season, solar cycle, geographical location of GNSS receiver and the magnetic field of the Earth (Warnant and Pottiaux, 2000).

In general terms, the complex structure of the ionosphere emerges as the most important obstacle in GNSS positioning. GNSS signals are affected by electrons on the path they follow until arriving at the receiver. The correction to be brought to this effect reaches its maximum values in the months of the equinox and in the winter months (March, April, September, October), and minimum values in the summer months (Kahveci, 1997) While the effect demonstrated by the ionosphere during the night is 10 nano seconds (about 3 m) it reaches up to 50 nano seconds (about 15 m) during daytime (Klobuchar 1987). While the ionosphere layer reflects frequencies below 30 MHz, it affects the high - frequency radio-waves (Klobuchar 1991).

### 2.1 The Structure of the Ionosphere

The ionosphere is divided geographically into three major regions: the high latitude region, the middle latitude region and the equatorial region (Figure 1a). These regions are taken as the base in scientific studies. The high latitude region between 55-90 latitudes is divided into two as the auroral and polar regions. The area covering the 55-67 latitudes represents the auroral region (Datta-Barua 2008). The ionospheric delay is lower due to the ultraviolet (UV) rays showing a low ionization tendency in this region during daytime. The polar region is located at upper latitudes of the auroral region. At these latitudes, the dense electron groups are formed as 50 – 1000 km long clusters. These dense electron clusters are located at the F2 layer and the scintillations occur in this region. The TEC value in this region is low, but the sudden changes occurring in the range generally prevent determination of the overall behaviour of TEC. Ionization in this region realizes as a result of both the Sun's rays and inter-particle collisions. The mid latitude region located between latitudes 20-55, in which Turkey is also found, is the region where TEC changes happen least. Few occurrences of change ensure

advantages in terms of overall behaviour of electron quantity to be known, and the change usually emanates from X-rays and ultraviolet rays. The reason why devices and equipment that observe ionospheric changes are found here, is that a major part of countries that conduct studies are located in the middle latitude region (Arslan 2004), while the equatorial region is the region where the total electron quantity change happens most. In particular, changes in certain sections of the equatorial region are twice as likely than in the middle

latitude region. The decrease in the number of electrons occurs due to reasons like magnetic storms and earthquakes, and can be expressed as an Appleton anomaly. This anomaly reaches its maximum level at 14:00 local time (Gizawy, 2003), also, in this region, as with the high latitude region, it is quite difficult to determine a general TEC behaviour.

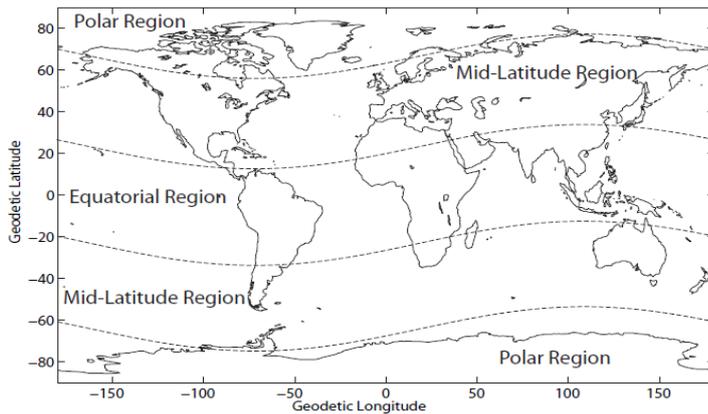
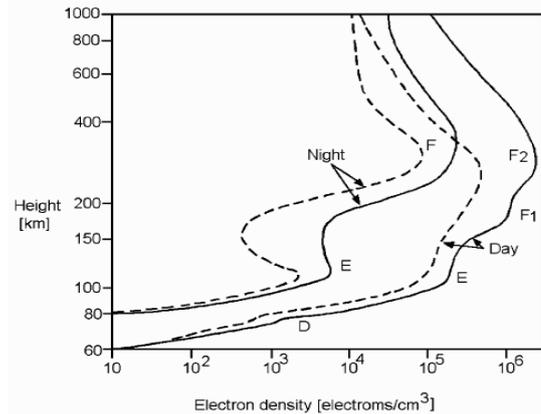


Figure 1. a) Ionosphere regions (Memarzadeh, 2009)



b) Ionosphere layers (Hargreaves, 1992)

The ionosphere layer consists of 4 different layers; D, E, F1 and F2 (Figure 1b). Each of these layers, caused by the severity of ionization, behaves differently during the day. Layer D is between 60 km and 90 km. It occurs under the influence of strong X-rays. It also contains neutral atoms as well as free atoms (Tileylioglu 2007). It is considered that this layer does not have significant effects on GNSS measurements. Long waves are reflected from this layer back to Earth. The layer between 90 km and 140 km is called Layer E. This layer has been formed by the effect of weak X-rays. The effect of the layer is minor in comparison to GNSS measurements. Partial ionization occurs frequently at Layer E. This event is called irregular E. This ionization is not thought to be related to Layer E during daytime. The anomaly caused by the effect of sunlight at this layer causes the deflagration in the arctic region (Arslan 2004). Medium and short wavelengths are reflected from this layer back to Earth.

The layer covering approximately 140-200 km is called Layer F1. The effect of this layer combined with Layer E is 10% on GNSS signals. Propagation at F1 layer is not significant, but it has a predictable electron density. The F2 layer is the region where the anomalies are most dominant in terms of electron density, while its effect on the GNSS measure is rather high (Arslan 2004). The maximum range of electron density at the F2 layer covering about 200-1000 km varies between 250-400 km. This value may vary with factors such as magnetic storms, night time and equatorial zone (Petrie et al. 2011).

Medium and short wavelengths are reflected from this layer back to Earth. While the layers D, E and F1 form the middle part of the ionosphere, F2 and above form the upper part of the ionosphere.

Since the ionosphere is a scattering medium, TEC values can be determined with the assistance of L1 and

L2 carrier signals sent from GNSS satellites. TEC values contain information on global or regional ionosphere structure (Fedrizzi et al., 2001, Davies and Hartmann, 1997).

The local (regional) TEC map is obtained by applying the Taylor expansion to the L4 linear combination equal to the difference between L1 and L2 phase measurements.

$$L4 = L1 - L2 \quad (1)$$

To model the effects of the global ionosphere, the spherical harmonic expansion is used because the Taylor expansion in the regional quality remains insufficient. Global TEC maps created at 5 different centres are available in IONEX format (URL 1) and the global TEC model can also be obtained with Bernese GNSS software (Arslan, 2004).

Changes of the TEC in the ionosphere may be determined by GNSS observations before, during and after earthquakes (Ulukavak and Yalçinkaya, 2014). Electrical and magnetic field changes may occur in an earthquake area and its vicinity due to earthquakes. As these changes proceed to the atmosphere, the electron density of the ionosphere changes due to the uniting of the neutral atmosphere and ionized plasma (coupling) (Calais et al., 1998). Before large volcanic eruptions, the rate of occurrence of TEC anomalies are related to volcanic type and geographical location (Li et al., 2016). Thus, the effects of earthquakes and volcanic eruptions may be monitored (Basciftci et al, 2017b).

### 3. IONOSPHERIC MODELS PRESENTED BY THE INTERNATIONAL GNSS SERVICE (IGS)

Many institutions across the world produce a global ionospheric TEC map (GIM). These institutions are:

ESA / ESOC (European Space Operations Centre, Germany), JPL (Jet Propulsion Laboratory, California), NOAA (National Oceanic and Atmospheric Office, USA), CODE (Centre for Orbit Determination in Europe, Switzerland), DLR (Fernerkundungstation Neustrelitz, Germany), NRCan (Natural Resources, Canada), ROB (Belgium Royal Observatory, Belgium), UNB (New Brunswick University, Canada), and UPC (Catalan Polytechnic University) (Schaer, 1999; Basciftci et al, 2017b). A global ionosphere map (GIM) is published in IONEX (IONosphere map EXchange) format. TEC data in IONEX format are arranged to cover the whole world. The desired TEC value can be obtained from this sequence. If the latitude and longitude of a point are known, the TEC value is obtained for the nearest 4 TEC values that incorporate two variable interpolation points (Schaer et al., 1998). When the value calculated to determine the TEC in the TECU unit is multiplied by 0.1, the TEC value of the relevant point is determined in TECU units. IONEX – formatted global ionosphere maps are produced in 2-hour intervals. For TEC values, the increase in the longitude is 5° and the increase in the latitude is 2.5° (Arslan, 2004). The accuracy of TEC values published in IONEX format varies between 2-8 TECU. In recent years, studies using ionospheric models of CODE, ESA, JPL and IRI have been widely used (Gao et al, 2002; Liu et al, 2005; Mao et al, 2008; Liu et al, 2009; Hernández-Pajares et al, 2009; Scharroo and Smith, 2010; Ya'acob et al, 2010; Wan et al, 2012; Bilitza et al, 2014; Leong et al, 2015).

Using the data from approximately 200 GPS stations of CODE, Bern University, Switzerland: CODE Global Ionospheric Maps (GIMs), IGS and other institutions, the CODE Global Ionospheric Maps (GIM) are produced on a daily basis. Up to 15 degrees, Vertical Total Electron Content (VTEC) has been modelled using a spherical harmonic expansion in the solar-geomagnetic reference framework.

ESA, Darmstadt, Germany: VTEC values are determined by vertical integration onto the Chapman Profiler model using the carrier phase level for cosz and code observables as a mapping function.

JPL, Pasadena, United States of America: Vertical TEC (VTEC) has been modelled on a solar – geomagnetic reference plane using a bi – cubic spline on a spherical grid. The Kalman filter is used on the grid to solve VTEC and instrumental biases at the same time (such as the stochastic parameters).

The IRI model has been produced in collaboration with the International Union of Radio Science (URSI) and the COmmittee on SPace Research (COSPAR), and has been periodically developed and improved. The latest version of the model is IRI-2012 (Bilitza et al, 2014). IRI can provide a lot of parameters related to the ionosphere, including the TEC value for ionospheric heights between 60 km and 2,000 km depending on location, date and time (Leong et al, 2015). Thanks to the IRI-2012 programme, TEC values (URL 2) can be calculated online from the internet address together with the latitude and longitude values of the corresponding day. The model makes calculations over six different parameters: electron density, electron temperature, ion content, ion temperature, ion drag and total electron content (Inyurt, 2015).

Solutions can be downloaded from the page of the

IGS data centre (URL 1). Until now, no inconsistencies have emerged in the solutions published by different analysis centres.

#### 4. DETERMINATION OF A REGIONAL IONOSPHERE MODEL (RIM) WITH BERNESE GNSS SOFTWARE

A regional ionospheric model with high accuracy can be determined using Bernese GNSS software (Todorova et al, 2003) by calculating VTEC values from specific points without the need for interpolation.

Prior to activating the program in the flow chart in Figure 2, the following files, which are updated from time to time by the Bern University Astronomy Institute, must be introduced to the program. These files are required to be consolidated under C: \ BERN52 \ GPS \ GEN folder (URL3).

COST	DATUM
EGM2008_SMALL	GPSUTC IO8.ATX
IAU2000R06.NUT	IERS2010XY.SUB
IONEX	IONEX.PPP
OT_FES2004.T10	PCV.IO8
POLOFF	RECEIVER
s1_s2_def_ce.dat	SATELLIT.IO8
SINEX	SINEX.PPP
SINEX.RNX2SNX	TIDE2000.TPO

Before the program is run, the satellite problem file (SATyyy.CRX) belonging to year of resolution should be placed in C: \ BERN52 \ GPS \ GEN folder (URL3).

The DATAPOOL folder where the raw data belonging to the day when the solution will be performed is filled in. Under this scope, the following files should be found under this index:

- In the index of BSW52; CODwwwwd.TRO, CODwwwwd.ION, P1C1yymm.DCB, P1P2yymm.DCB, P1P2yymm\_ALL.DCB (URL3)
- In the index of COD; CODwwwwd.CLK, CODwwwwd.EPH, CODwwwww7.ERP, CODwwwww7.SNX, CODwwwww7.SUM (URL3)
- In the index of IGS; iglwwwwd.sp3, iglwwwww7.sum, igswwwwwd.clk, igswwwwwd.sp3, igswwwwww7.erp, igswwwwww7.sum (URL1)
- In the index of REF52; \*.CRD, \*.VEL, \*.STA, \*.PLD, \*.ABB, \*.ATL (to be created with the Bernese program based on .CRD file), \*.BLQ (URL4) with .CRD from internet address), IGS.FIX, IGS08\_R.CRD, IGS08\_R.VEL (URL3)
- In the index of RINEX; there must be 24-hour raw data of the stations which are going to be solved and taken as a reference.
- In the index of VMF1; VMFG\_yyyymmdd.H00, VMFG\_yyyymmdd.H06, VMFG\_yyyymmdd.H12, VMFG\_yyyymmdd.H18, VMFG\_yyyymm(dd+1).H00 (URL5)

Then, the relevant campaign (session) needs to be defined for the day to be resolved in the program. The following process steps are performed in defining the relevant session.

BERNESE >> Campaign >> Edit list of campaign

BERNESE >> Campaign >> Select active campaign  
BERNESE >> Campaign >> Create new campaign

At this stage, the time of data to be solved is introduced into the program. In definition of time to the program at this section, entering either one of the information for Year-Month-Day / Modified Julian day / GPS week-day of the week or Year - day of year. The process step to be followed in this step is;

BERNESE >> Configure >> Set session/compute date

To prepare and define the solution time for the data to be solved at this stage, the automatic solution starts with;

BERNESE >> BPE>> Start BPE processing >> PPP\_DEMO.PCF

If no error message is encountered at the end of activating the program, TEC values pertaining to the day related to the RIMwwwd.INX file under the campaign folder whose solution is being actualized in the ATM index or under SAVEDISK >> PPP >> YEAR >> ATM folder are obtained.

In the evaluation, an automatic process was performed using the Bernese v5.2 GNSS software ready command PPP\_DEMO.PCF and regional TEC values (RIM \*.INX) were obtained.

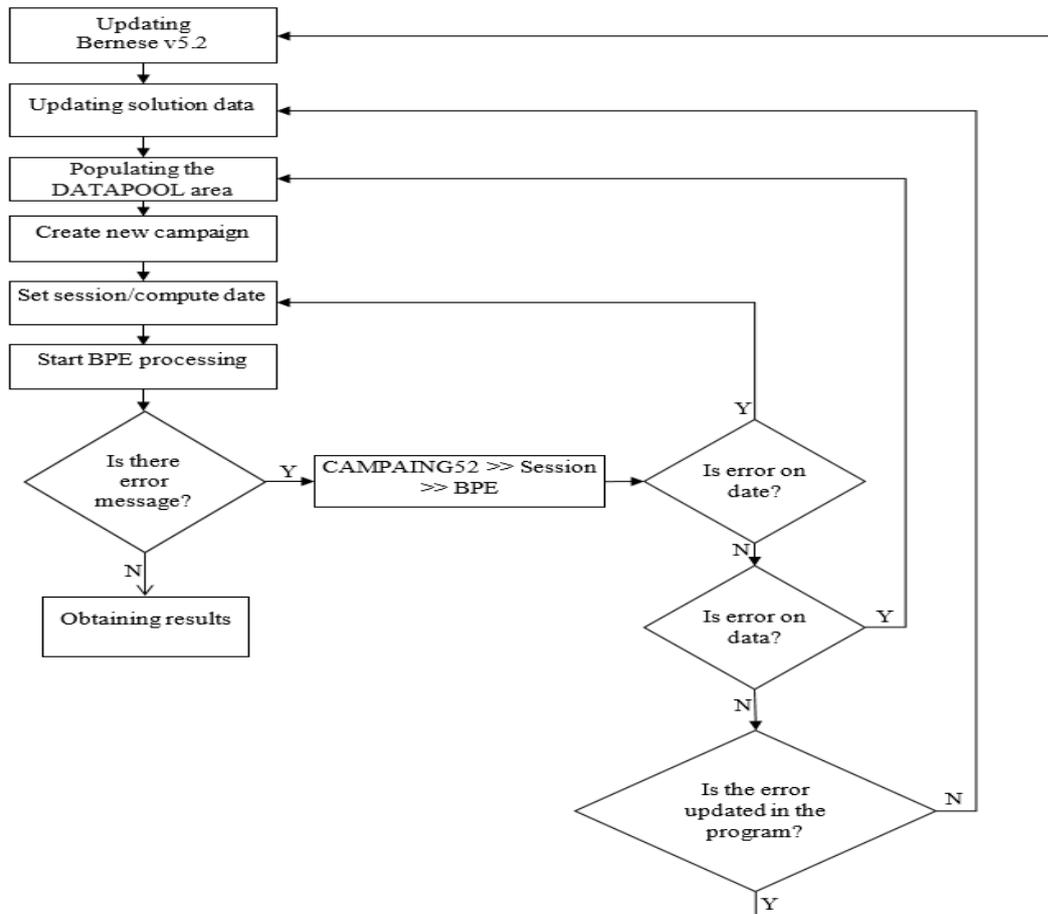


Figure 2. Workflow diagram for obtaining TEC values in Bernese v5.2 GNSS software

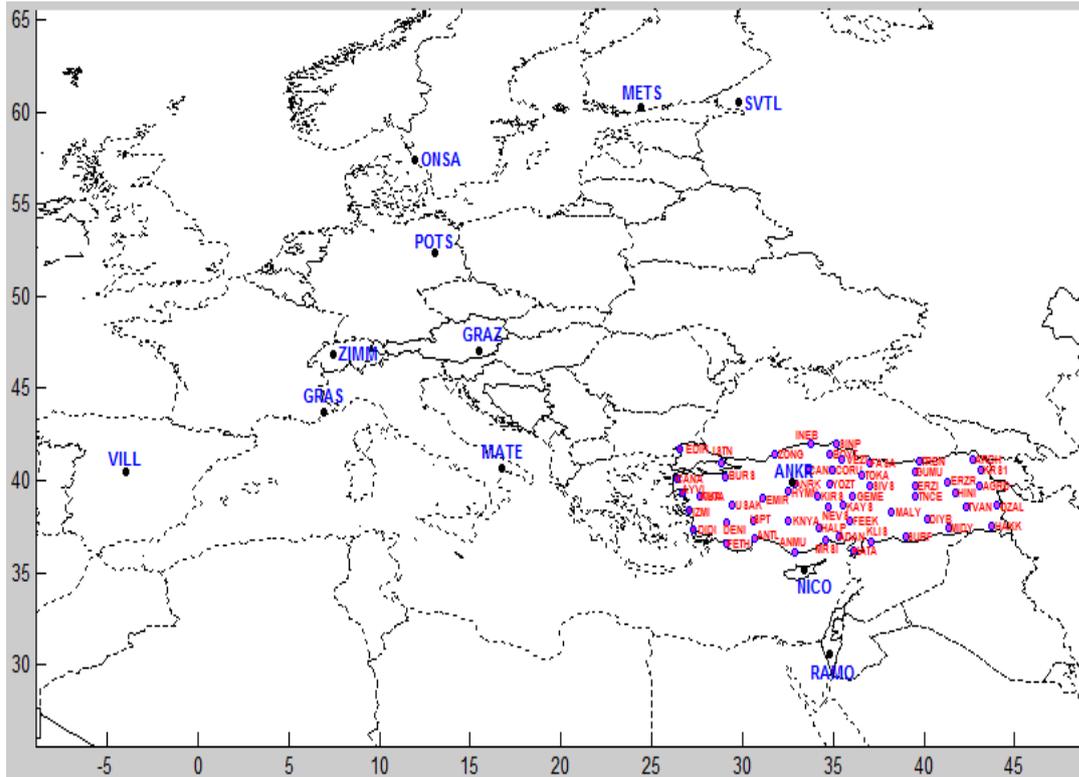


Figure 3. GNSS network used in the study

## 5. APPLICATION

In this study, TEC values for Turkey from 2009 to 2015 are calculated. The regional TEC model has been used in the assessments made using Bernese v5.2 GNSS software. In the study where the single – layer model was employed, the height has been taken as 450 km. The height of the ionosphere is accepted as 450 km by softwares and it is assumed that TEC being at this height is at its highest value. In order for the produced TEC values to be compared, the GIM values produced by CODE, ESA and JPL, and the IRI-2012 model developed by COSPAR and URSI have been used.

CORS-TR and IGS stations used in the analysis are shown in Figure 3. In the study, where a total of 68 stations were used, 56 of them are CORS-TR stations and others are IGS stations. The data for the CORS-TR stations have been obtained from the address URL 6 and

the data pertaining to IGS stations from URL 7. The TEC values obtained as a result of the evaluation are plotted by MATLAB R2014a. As a result of the analysis, regional TEC values have been obtained from 2009 until 2015. To compare the regional TEC values obtained from the GNSS software with Bernese v5.2 GNSS, GIM-TEC values published by CODE, ESA and JPL, obtained by IRI, have been downloaded from the URL 1 address, and by entering the latitudes and longitudes belonging to the TEC values – related day obtained from IRI, this has been calculated online from the URL 2 address.

As a result of the evaluations, the mean of the TEC values from 2009 until 2015 was calculated and compared with IRI and GIM (JPL, ESA, CODE) mean TEC values (Figure 4-7). Since all of the stations in the study showed similar behaviour, only 4 stations which can be represented Turkey are given as examples.

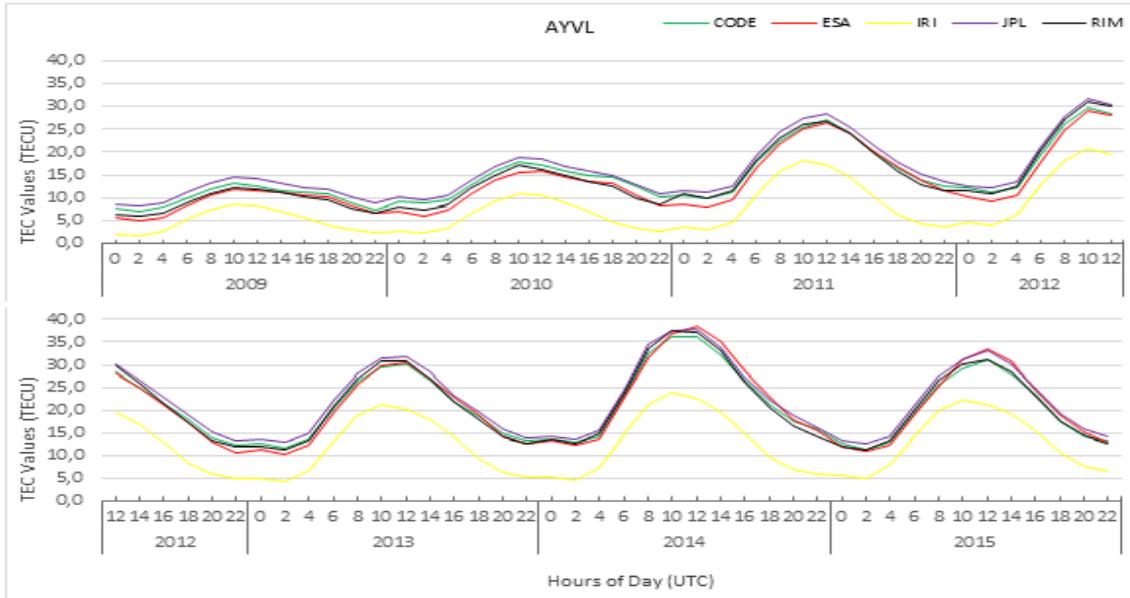


Figure 4 Comparison of average TEC (RIM-Result) values obtained for AYVL station between 2009-2015 with CODE, ESA, JPL, IRI values

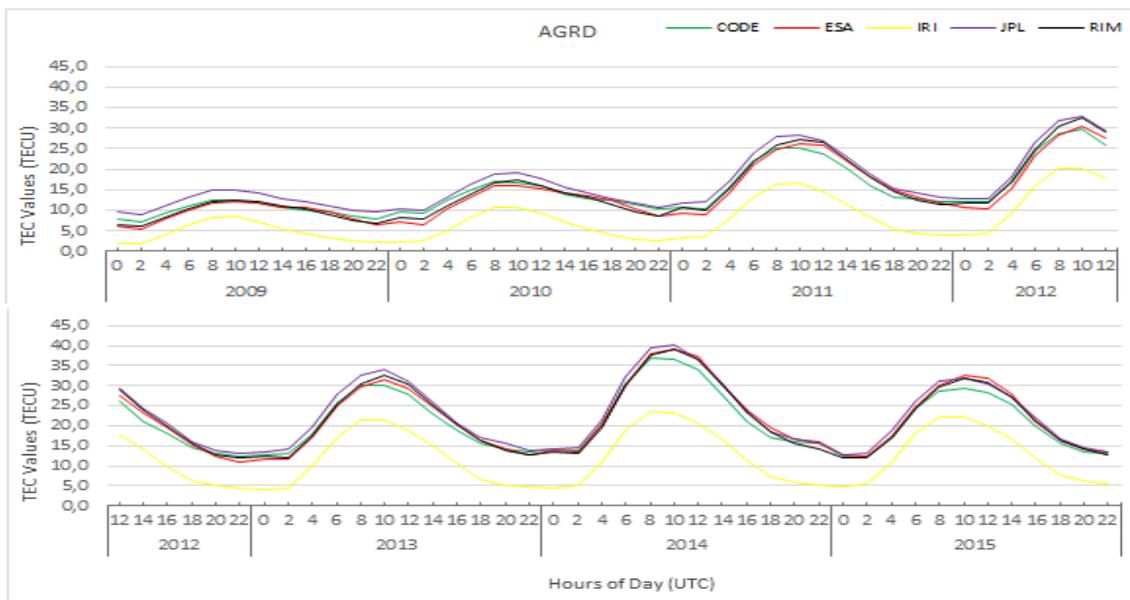


Figure 5. Comparison of average TEC (RIM-Result) values obtained for AGRD station between 2009-2015 with CODE, ESA, JPL, IRI values

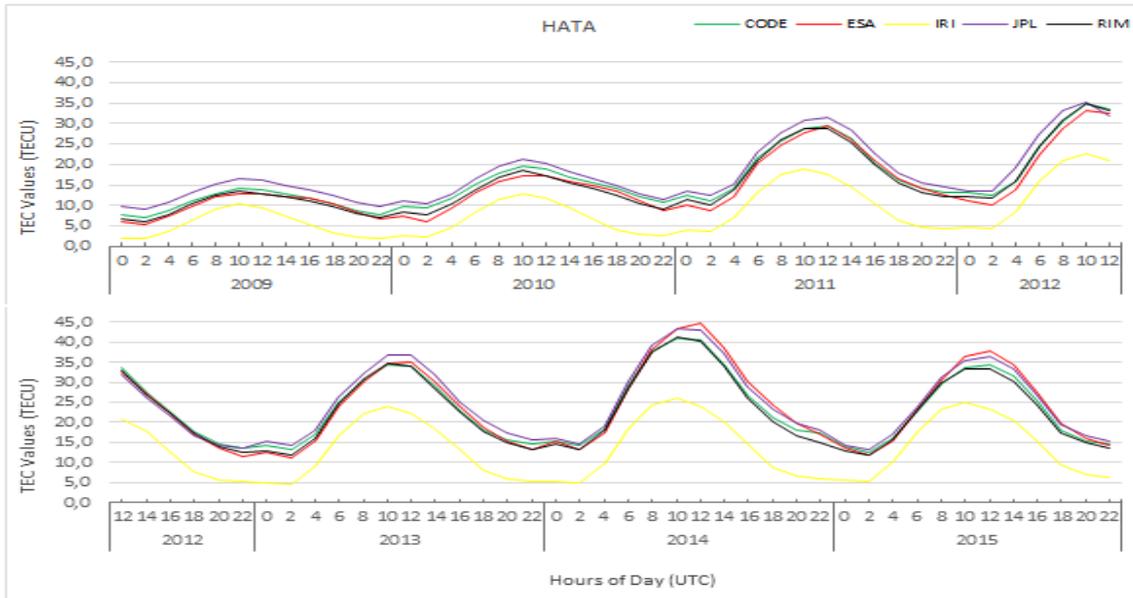


Figure 6 Comparison of average TEC (RIM-Result) values obtained for HATA station between 2009-2015 with CODE, ESA, JPL, IRI values

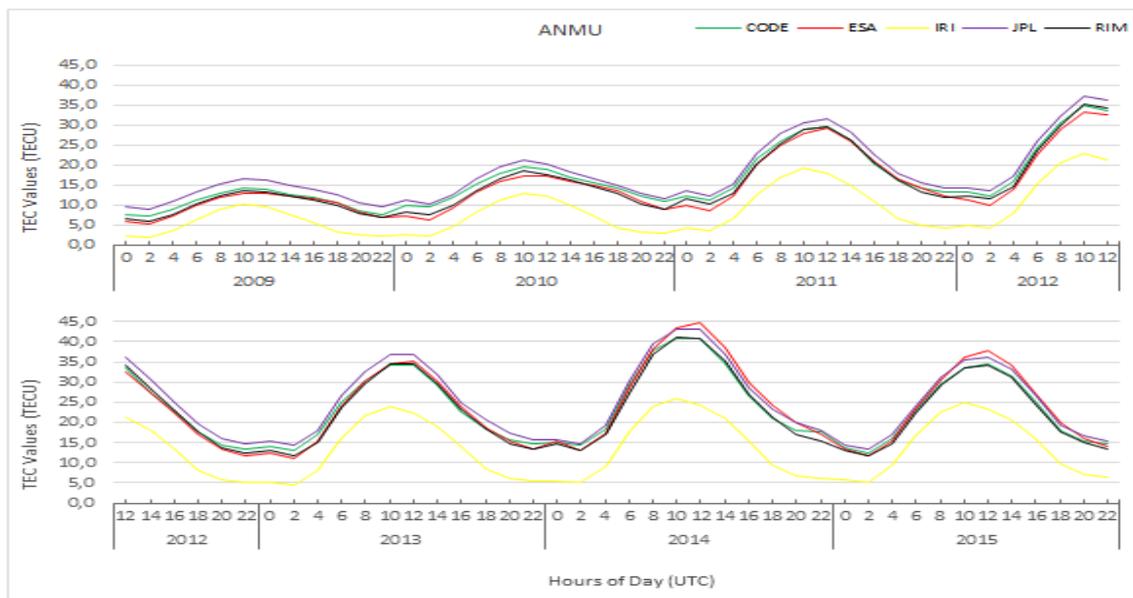


Figure 7. Comparison of average TEC (RIM-Result) values obtained for ANMU station between 2009-2015 with CODE, ESA, JPL, IRI values

The average TEC has been produced by utilization of TEC values estimated in the above figures and they have been compared with the average values between 2009 and 2015.

When Figures 4-7 are considered, the TEC values obtained from the regional ionosphere model (RIM), the global ionosphere model (CODE, ESA, JPL), and the IRI model, have generally been increasing with the regional ionosphere model (RIM) at 02:00, and reached their maximum value at 10:00. This shows that it began to decrease from 12:00, its density was at a minimum value between at 02.00, and at minimum values between 10:00 – 12:00.

Table 1 gives the minimum, maximum and average values of TEC (RIM) values obtained as a result of the evaluation, and TEC values obtained from IRI and Global Models (CODE, ESA, JPL) from 2009 to 2015.

As a result of the analysis, to determine the correlation level between regional TEC values and Global (CODE, ESA, JPL) and IRI TEC values, the correlation between the regional and global models from 2009 until 2015 was determined. This is shown in Table 2.

Table 1 Test statistics for regional and global models (TECU)

Test Statistics	Years	Regional		Global (GIM)		
		RIM	CODE	ESA	JPL	IRI
Minimum	2009	5.40	6.93	4.91	8.09	1.63
	2010	6.85	8.81	5.91	9.26	2.05
	2011	9.32	9.59	7.75	11.07	2.68
	2012	1.14	10.80	8.74	11.94	3.74
	2013	10.63	11.42	10.22	12.52	3.90
	2014	11.97	12.55	12.02	13.49	4.37
	2015	10.49	10.88	10.40	12.00	4.62
Maximum	2009	13.40	14.23	12.94	16.62	10.33
	2010	18.63	19.54	17.21	21.37	12.96
	2011	29.67	29.49	29.27	31.59	19.09
	2012	35.22	34.83	33.28	37.12	22.78
	2013	34.84	34.28	35.09	36.84	23.92
	2014	41.29	40.96	44.71	43.27	25.98
	2015	34.24	34.46	37.76	36.33	25.11
Average	2009	9.09	10.08	9.11	11.89	4.78
	2010	12.05	13.42	11.82	14.48	6.09
	2011	17.77	17.72	17.45	19.53	9.25
	2012	19.83	19.53	18.85	21.22	11.27
	2013	20.38	20.44	20.31	22.15	11.86
	2014	24.03	23.98	24.92	25.51	13.05
	2015	20.46	20.31	21.27	21.84	12.97

Table 2 Correlation between regional (RIM) TEC values and global (CODE, ESA, JPL) and IRI from 2009 until 2015

	Years	RIM - CODE	RIM - ESA	RIM - JPL	RIM - IRI
Correlation Among Regional and Global TEC Values	2009	99.3%	98.3%	99.5%	96.3%
	2010	99.2%	97.2%	99.7%	97.5%
	2011	99.6%	98.9%	99.8%	98.7%
	2012	99.8%	99.6%	99.9%	99.5%
	2013	99.8%	99.7%	99.9%	99.3%
	2014	99.7%	99.4%	99.8%	99.0%
	2015	99.9%	99.6%	99.9%	98.3%

It can be seen that the TEC values were close to GIM TEC values obtained from the Global ionosphere map, and are very different to the IRI-2012 TEC values.

## 6. CONCLUSION

Studies on determining the TEC value have increased in recent years. In this study, TEC values have been obtained from 68 GNSS stations. These include 56 CORS-TR stations that are located in Turkey and 12 IGS stations. Evaluation of GNSS measures was carried out with Bernese v5.2 GNSS software developed by Bern University, Switzerland.

Regional (RIM) TEC values were obtained from 2009 to 2015. The results are compared with the average values of CODE, ESA, JPL published GIM values and IRI-2012 TEC values (Figures 4-7).

The TEC values obtained from the global ionosphere models (CODE, ESA, JPL) begin to increase at 02:00 and they reach their maximum values at 12:00. In

general, the global TEC values are at their lowest value at 02:00 and their highest value between 10:00 and 12:00. It was found that the TEC values obtained online in the IRI model are at their lowest value at 02:00 at night, and the highest value at 10:00. In the regional ionosphere model (RIM), the resulting TEC values began to increase at 02:00 and rise to 12:00, as in the global ionospheric models. In general, it is seen that RIM-TEC values are at their lowest value at 02:00, similar to the global TEC values, and at their highest value between 10:00 and 12:00 (Figures 4-7, Table 1).

When the results are examined, there is a great similarity between regional (RIM) TEC values and global (CODE, ESA, JPL) TEC values, and the TEC values obtained from IRI-2012 are lower than the four values. It is generally seen that the five TEC values obtained increased until noon, and then the TEC values decreased due to the recombination of the ions in free state. The reason that the IRI-2012 TEC estimates in

Turkey are lower than the other models may be due to the lack of ionosonde stations.

The minimum, maximum and average TEC values of regional TEC values, global TEC (CODE, ESA, JPL) and IRI TEC values obtained from the end of 2009 until the end of 2015 were determined (Table 1). It is seen that the minimum, maximum and average TEC values determined when examining Figures 4-7, and the TEC values of the points in Table 1 give similar results

When Table 2 is examined, there is a positive and high-level relationship between regional (RIM) TEC values obtained from the results of the analysis, and the global TEC obtained from the URL 1 and URL 2 addresses.

For all the stations that are planned to be used in Turkey, especially the CORS-TR stations, it is necessary to establish a system that will continuously monitor changes in the TEC value which is the most important function of the ionosphere and to increase the positional accuracy and to studies about earthquake, volcanic eruptions, determining the location of the missile will be an important contribution to their work.

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Research Article*

## **REAL TIME VECTOR DATABASE UPDATING SYSTEM: A CASE STUDY FOR TURKISH TOPOGRAPHIC VECTOR DATABASE (TOPOVT)**

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**ABSTRACT:** Turkish Topographic Vector Database (TOPOVT) is a 3D vector database comprising 1:25.000 scale or higher resolution topographic features, contours representing the topography and geographic names. TOPOVT is the basic geographic data source for our country mapping and base for GIS applications covering whole Turkey. So far data collection for TOPOVT has been carried out by General Command of Mapping. Updating of TOPOVT is a continuous process and goes on by annual planning on regional base.

Geospatial data collection, either in the office or in the field, is a hard, costly and time consuming process. Using the existing geospatial data will be a suitable solution for get rid of all these expenses. Governmental institutions and municipalities have their own GIS and collect and update these geospatial data according to their needs. With a close look, these data are similar to TOPOVT data or with a little effort can be converted to TOPOVT model.

TOPOVT Real Time Updating System was designed to provide all governmental institutions and municipalities producing and using geographic information via internet to update and easily access to TOPOVT. TOPOVT Real Time Updating System has been realized to avoid duplicate geographic data production countrywide and reflect the changes in topography to TOPOVT in real time or near real time. This system will enable governmental institutions and municipalities to update TOPOVT in their service areas according to their job definition without needing another software thus providing the TOPOVT users to make use of the up-to-date data.

By this system, all the governmental institutions needing topographic database for their applications will easily reach TOPOVT, make use of the data in their field works and present the data they produced to country use. Also, by avoiding the duplicate geographic data production, national sources will be utilized economically and effectively.

**Keywords:** TOPOVT, Real Time Updating, Topographic Feature, Vector Database

## 1. INTRODUCTION

General Command of Mapping (GCM) is responsible for the production of maps for defense and development purposes and provide geographic data to governmental institutions according to the regulations. In order to realize this responsibility effectively, Turkish Topographic Vector Database (TOPOVT) was established with a model representing the real world continuously with vector data without file base. TOPOVT is the topographic vector database in which the 1:25.000 scale topographic data produced by General Command of Mapping are stored and presented and also standard topographic printed maps are produced.

The vector data in TOPOVT is acquired mainly from stereo aerial photos by digital photogrammetric workstations and then completed in the field by checking the compiled data, correcting the mistakes and collecting the attributes of the features and also the geographic names. After field completion the data are post-processed, topologic rules are controlled and then uploaded to TOPOVT (Canıberk et al. 2014)

At the design stage of TOPOVT, all collected features in classical map production are investigated for their integrity, collection rules and topologic relations. New topographic feature classes and subtypes are determined by making use of VMAP (Vector Map) data model. The attributes and attribute values of these features are also determined; UML (Unified Modelling Language) diagrams are designed showing the topographic features, attributes, lower bounds, attribute values and transformation tables (Canıberk et al. 2014).

UML is a standard that enables visual representation of system components and their relationships. UML is not a programming language but covers the entire system development process. A good modeling during the analysis and design phase prevents many problems that may arise in the software phase (Booch et al. 2005).

The spatial Web standards produced by the Open Geospatial Consortium (OGC) and the systems that work with spatial data generated by different data producers have become interoperable in the Web environment. OGC has published more than 30 standards so far. These are the ones most commonly used for Web mapping; Web Map Service (WMS), Web Feature Service (WFS), Web Catalogue Service (WCS).

With WMS service, it becomes possible to share maps over the network. In this service, the geographical data itself can be shared instead of the maps derived from it. These maps are presented in raster formats such as JPG, PNG and TIF. It can be said that this service is particularly suitable for maps that will be used as a base (Beaujardiere, 2006).

In the WFS service, it is possible to directly share the geographical data over the network itself. Vector data (point-line-polygon) is used instead of raster data. That is, many vector analyzes such as clip, buffer, intersection, shortest path analysis are performed with vector data obtained using WFS (Vretanos, 2005). With WFS, there is no direct data flow from the server to the client, and the client can also transfer to the server as if it were two-way data transfer. Users can make changes to the incoming data (insert, update, delete) and send it to the server and update the data. Such WFS services are

called Transactional WFS or WFS-T.

The data need for the applications in which the spatial analyses are carried out are not met by a single producer. These applications need attribute information together with spatial information. The variety of these attributes directly influence the results of the application. The countrywide database are needed for the fulfilment of the requirement to the spatial data and attributes produced by different institutions in order to execute the mentioned applications. The different institutions or sides have to cooperate effectively to share the data they collected for establishing and sustaining these databases.

Today, the spatial information is the base for every kind of planning work. For this reason, the most important factor in healthy decision making is the working on accurate and up-to-date geographic data in planning works. The applicability of the planning is related to the availability and up-to-dateness of the data (Önder, 2000).

Different application fields, such as earth sciences, natural resource management, environmental protection, urban and regional planning, defense, transport, tourism, statistics and education need geographic data, because they require regional or countrywide analyses. Spatial data are generally related to resolution/scale and they have to be analyzed and presented with the resolution/scale that modelled phenomenon and processes were the best understood (Weibel and Dutton, 1998; Başaraner and Selçuk, 2004). In this context, TOPOVT is trying to fulfill the users' spatial data needs according to resolution, scale and up-to-dateness; it also assumes a role in effective use of national sources and avoiding duplicate productions.

Although it assumed that keeping the national spatial databases up-to-date is the responsibility of national mapping institutions, it is also the responsibility of the partners who need and produce spatial data. The updating process is mainly carried out by photogrammetric compilation and field works. Hanson and Wolff (2010) are defined these solutions as time consuming and expensive; thus failing to respond effectively to update requests. Müller and Heipke (2009) have achieved a 65.5% success rate in the method they developed for the semi-automated updating and control of large-scale databases using aerial photos at 10 cm resolution. However, it can be foreseen that it will be difficult to implement it on a country basis because the method they apply will lead to keep the institutional database updated with only institutional capabilities.

Coumans (2016) is stated in her article that Ordnance Survey Ireland (OSi) was designed a topographic database that 1:1,000,000 cartographic products could be produced from 1:1,000 topographic database in an automated workflow. OSi geared to present real features to the users by combining the efforts to collect data in different scales. OSi has combined efforts to produce spatial data by avoiding duplicate works on different scales.

Ordnance Survey of UK is the national mapping agency of Great Britain. They deal with 234.000 km<sup>2</sup> area and try to present most up-to-date maps to their customers. They split revision policy into two stages as continuous and cyclic revision. In continuous revision, most important features, namely buildings and roads, are

captured in upmost six months' time after the construction. Cyclic revision deals with gradually

changing features especially to the national environment. Data capture for cyclic revision is carried out at fixed intervals. Capture priority is also divided into four categories according to cyclic revision periods. More prestigious or important features (such as roads, public places like hospitals, schools and sport areas) for people are captured in short time periods. (Ordnance Survey, 2018)

Moore (2013) pointed out that U.S. Geological Survey's (USGS) national 7.5-minute topographic map series was completed in 2000. He asserted that one sheet of map would cost more than \$50,000 per map (in 2007 dollars) and would take 45 years to complete the series in traditional method. By using the available different resolution and different accuracy level GIS sources countrywide, USGS achieved three years updating cycle and cheaper production expenses than the original topographic maps by at least a factor of 100.

A newly emerging paradigm, namely volunteered GIS (VIG) is effecting the geographic information collection phenomenon. This kind of geographic information is derived from ordinary volunteered people, in a sense it is crowdsourced. VIG is executed via web applications or mobile phone applications. One of the most successful VGI application is OpenStreetMap (OSM). OSM produced data in some places are claimed to be more accurate and detailed than the officially produced maps of that place. By the help of the volunteers, the geographic information is collected or updated immediately in urgent circumstances (Fast and Rinner, 2014).

USGS also seeks volunteers to contribute The National Map (TNM). They call the volunteers as The National Map Corps (TNMCorps). In this project USGS urges from TNMCorps to update existing data and collect non existing data. Especially, the volunteers are requested to give the location of community buildings like schools, hospitals, fire stations etc. USGS informs its volunteers that TNM data collected by VIG yields accurate and up-to-date information to the citizens (USGS, 2013).

İşcan and Ilgaz (2017) governmental GIS applications and geospatial data. They proposed that all governmental institutions should use same geospatial data model, namely a common geospatial infrastructure.

The tendency in geospatial data production is towards avoiding multi-production efforts on the same location as it is seen in the above mentioned production examples.. While the countries are seeking the ways to reduce the geospatial data production expenses, they are also trying to save labor and time. As a result of these efforts, they manage to produce more up-to-date geospatial data on broader areas of interest. Consequently, General Command of Mapping, the national mapping agency of Turkey, initiated a project to unite all geospatial data production efforts so as to allow all governmental institutions to share and to contribute Turkey's geospatial data.

This paper defines the problem in the second chapter; propose an updating system design which has already been put into practice in the third chapter; and lastly draw some conclusions and suggests some actions for future works.

## 2. PROBLEM DEFINITION

Geospatial data collection, either in the office or in the field, is a hard, costly and time consuming process. Using the existing geospatial data will be a suitable solution to get rid of all these expenses. So far, the data collection for TOPOVT has been carried out by General Command of Mapping. Updating of TOPOVT has always been a continuous process and goes on by annual planning on regional base.

Governmental institutions and municipalities have their own GIS and collect and update these geospatial data according to their needs. With a close look, these data are similar to TOPOVT data or with a little effort can be converted to TOPOVT model. The design of the proposed Real Time Updating System is expected to solve to unite nationwide geospatial data collection and updating efforts.

## 3. REAL TIME UPDATING SYSTEM DESIGN

It is also an important and ambitious work to live as long as the creation of the spatial databases (Cömert et al., 2009). The necessity of digital geographical information is in the tendency to increase continuously; by reviewing the digital geographical data produced, the data model used in production needs to be updated according to user needs and the design of geographic databases in accordance with this data model is required. TOPOVT is a structure that can respond to user needs in this context.

With the establishment of TOPOVT; the ability of geographic data production to adapt to the efficiency and technological developments in the map production system has increased. Geographical data users are provided with the necessary data infrastructure for online geographic data support. Although the definition of the rules for the analysis, design phases and the loading of the database is very important as of the near future, nowadays it is left to update the database. From this perspective, the real-time database update system will take an important step toward reaching institutional targets (Canberk et al., 2015).

TOPOVT Real Time Updating System was designed to provide all governmental institutions and municipalities producing and using geographic information via internet to update and easily access to TOPOVT which is the basic data source of geographical map and topographic map production, which is the basis for GIS applications. TOPOVT Real Time Updating System design is depicted in Figure 1.

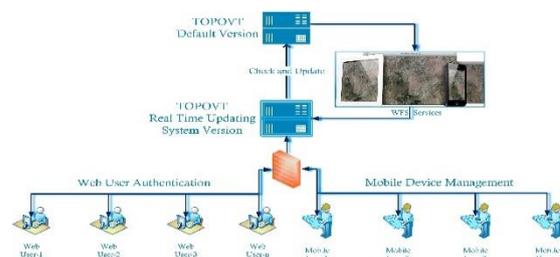


Figure 1. TOPOVT Real Time Updating System

### 3.1 Web Platform Updating System

The real-time topographic database update system requires the selection of data to be published, the identification of users and groups, and authorization procedures. After this process, the users will be able to connect from different platforms and perform add-delete-update operations.

Only authorized users are allowed to log in to the system via WEB interface provided that IP addresses are defined for the access. In addition, user input traffic is controlled by keeping all input/output records in the system. Thus, the access security of the system is ensured.

The system consists of data management and data transfer, topographic data entry and editing, layer drawing and attribute information entry, mapping, authorization and service integration layers. Welcome page of the system interface is presented in Figure 2.



Figure 2. Welcome page of the system interface (<https://topovt.hgk.msb.gov.tr>)

This web-based application can be reached through any internet browser. The defined reports, such as production amount of any feature layer or contribution of any user, can be obtained.

The authorization to the users are done according to region-based (Figure 3) and/or attribute-based. The attribute based authorization gives users the ability to see and/or update the attributes of the authorized features. The ability to add/delete/update features is also defined in this interface.

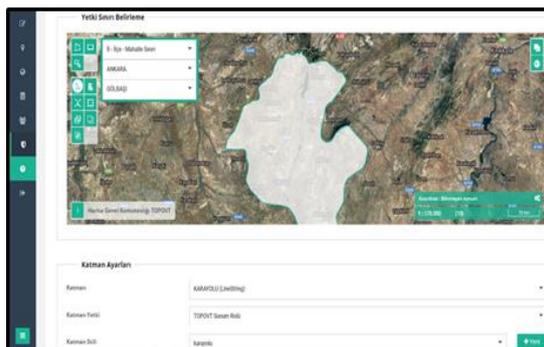


Figure 3. Zone-based authorization

All map submissions can be managed via a single platform with internal and external services. Vector data can be viewed and managed from web platforms on map layers; can be reported by hundreds of users within the authorities granted at the same time from the databases. In addition, the change of history-based topography can be observed. In addition, services such as WMS, WFS, WCS can be added dynamically and can be presented based on authority (Figure 4).

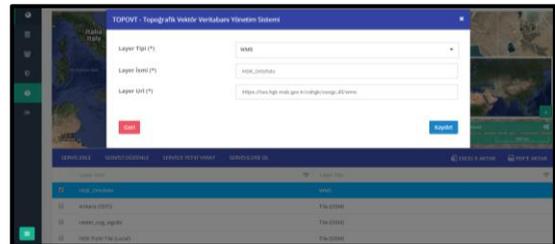


Figure 4. Service addition and authorization

System administrator provide public authorities and all other stakeholders to perform updating, addition, deletion and correction operations on the authorized area by performing authorization on the basis of layer, region, province, district, village, neighborhood and attribute and. The vector processing required to update TOPOVT from existing geographical data is executed fast, secure and data integrity ensured. To this end, tools that work in the internet interface and that can perform many basic geographic operations (cutting, cropping, merging, reshaping, etc.) are integrated into the system. Figure 5 shows the system-integrated geographic editing tools.



Figure 5. Geo-editing tools application

The system also enables the administrators to check and validate the updated data with a control unit. In this unit, all the changes that users made on TOPOVT are controlled one by one basis and validated as “accepted” or “rejected”. So the standardization and integrity of TOPOVT is preserved.

### 3.2 Mobile (Android) Platform Updating System

TOPOVT android application is designed for users who carry out data collection work in the field. This system will increase the efficiency of the field work, which is one of the TOPOVT data collection steps. The Android application will also be able to serve to the field

works of the institutions that will be the stakeholder of the update system.

A mobile platform update system is designed for users to access TOPOVT data with android data tablet computers in the field (Figure 6). The system is managed by Mobile Device Management System (MDM) and can be linked to the TOPOVT update infrastructure. The user access authority to the system is determined by MDM and can work integrated with the real time updating system. Android data tablets can be controlled remotely via the management console, messages can be sent to the tablet via the management console, such as resetting the system, turning GNSS on/off, locking the device. This ensures that both the tablet and the data in the tablet are safe. At the same time, the data downloaded to the disks of the tablets are protected by encryption algorithms, preventing unauthorized access to the data.



Figure 6. Tablet PC and external GNSS receiver

Software running on the android data tablet platform can access TOPOVT data, just like the software running on the browser, and perform add-delete-update operations within the authorities. Users can work in real time as well as download the data at the same time as the internet connection and send them to TOPOVT at the end of their work and they will be able to work in near real time.

Users see only the mobile update software on their tablets and cannot access any other settings and cannot run any programs. Separately authorized users for each tablet are directed to the main screen to log in to their tablets and the main application screen (Figure 7) is displayed with successful user input.

The main screen consists of four sections. These sections are; Settings Bar (1), Transaction Menu (2), Tools Menu (3), Map Module (4). All functions in these sections are active according to the user's authority.



Figure 7. Mobile application main screen

Mobile application vector contains many tools for data editing. These tools allow the user to edit on the existing geometry on the selected layer. The user can use these tools within his/her authority. Editing tools become active after feature(s) are selected. Single feature editing when a geometry is selected, multiple feature editing tools when multiple geometries are selected. The system has merge, clip, intersect, union, snap from node to node, split functions which are the basic geographic information system functions that facilitate data collection in the user interface (Figure 8).

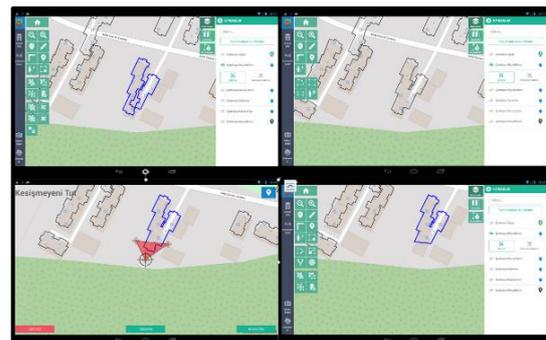


Figure 8. Geometry editing tools

An external GNSS receiver is plugged into tablets from the micro USB port and thus ensures feature collection at  $\pm 3$  m spatial accuracy. The GNSS receiver is compatible with Turkish CORS (TUSAGA Aktif). The accuracy can rise up to decimeter level with using Turkish CORS. The tablet application can detect the installed GNSS receiver and work with the external receiver. After connecting the receiver, all the information (satellite number, geometry etc.) from the receiver can be displayed. A new point or vertex can be added with the GNSS receiver, and existing geometries can be arranged according to GNSS coordinates (Figure 9).

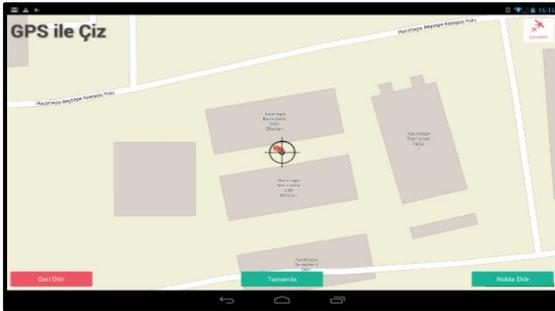


Figure 9. Feature collection with GNSS

#### 4. RESULTS AND DISCUSSION

TOPOVT is a database in which 1:25.000 or larger scale topographical data produced by the General Command of Mapping is held and presented, and at the same time standard topographic map production is performed which is one of the most important tasks of the institution.

Rapid development is observed in our country especially in urban areas. As a result of this development, when the newly created, changed or lost features are transferred to the database in short time intervals, the will of the users who need the up-to-date database will be met. For this reason, the establishment of a real-time updating system is important.

The developed system will provide public institutions and organizations and municipalities direct access to TOPOVT, and will facilitate data sharing among institutions. Thus, institutions will contribute to the updating of TOPOVT in line with their needs, and repetitive productions between institutions will cease to exist. With the real-time updating system, data can be updated at the same time by splitting large areas, integration of data produced or possessed by public institutions and organizations producing topographical data can be provided and all updates can be instantly controlled from a single center, TOPOVT.

With TOPOVT Real Time Updating System;

- The duplicate geographical data collections of institutions will be avoided,
- The geographical data will be kept up-to-date with labor and time saved from duplicate transactions,
- Emergency geographic data needs will be met shortly as there will be no bureaucratic procedures,
- Full and correct geographical data will be used and shared since missing features and errors are reported and corrected by the related institution.

Thus, TOPOVT can be updated with the geospatial data produced by the public institutions and organizations and the municipalities. In addition, data collection can be carried out between the institutions by collecting detailed geographical features similar to TOPOVT and making necessary changes in feature definitions and attributes to prevent duplication. Organizations will be able to contribute to the correctness and completeness of TOPOVT by noting errors and omissions.

Quality assurance may be provided by TOPOVT management until the users have a certificate at the

beginning of their works. Then quality control will be carried out by a certain percentage of the data entered, i.e. 10% of the data. Also the features will have feature level metadata about the owner/updater of the feature. So the responsibility of the accuracy of the data will be the owner/updater. Moreover, during the planned revision of TOPOVT quality will be assured by GCM either by stereo imagery or by field completion in at most five years changing according to the development level of the region.

Providing geospatial data to TOPOVT is also possible with WFS. In this case, a mutual schema of the features should be agreed in order to easily migrate different kinds of geospatial data.

The limiting accuracy is  $\pm 3$  m in planimetry and height for TOPOVT. The accuracy of most of TOPOVT data is better than  $\pm 3$  m. This accuracy might be improved according to the needs of the partners. Especially in urban areas, the accuracy and resolution of the TOPOVT might be greater than 1:5.000 scale maps by designing a multi resolution database.

There are of course challenges for the success of this proposed system. So far governmental institutions gathered geospatial data according to their needs in any available format and model. In fact, it is very difficult to provide these different kind of geospatial data to communicate each other. But this challenge can be overcome by working together on an agreeable schema to exchange geospatial data. Most important factor to make this project come into practice is the mutual will of all the shareholders.

In further studies, the outputs of the system can be discussed. Also, the refinements to the system are put forth.

For further applications, some improvements can be made in the TOPOVT Real Time Updating System to allow VIG to Turkish citizens in order to contribute their observations to a TOPOVT condensed version by their mobile phones. The volunteers can especially be requested to give location and name of the community buildings so as to present up-to-date and accurate information to other citizens.

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