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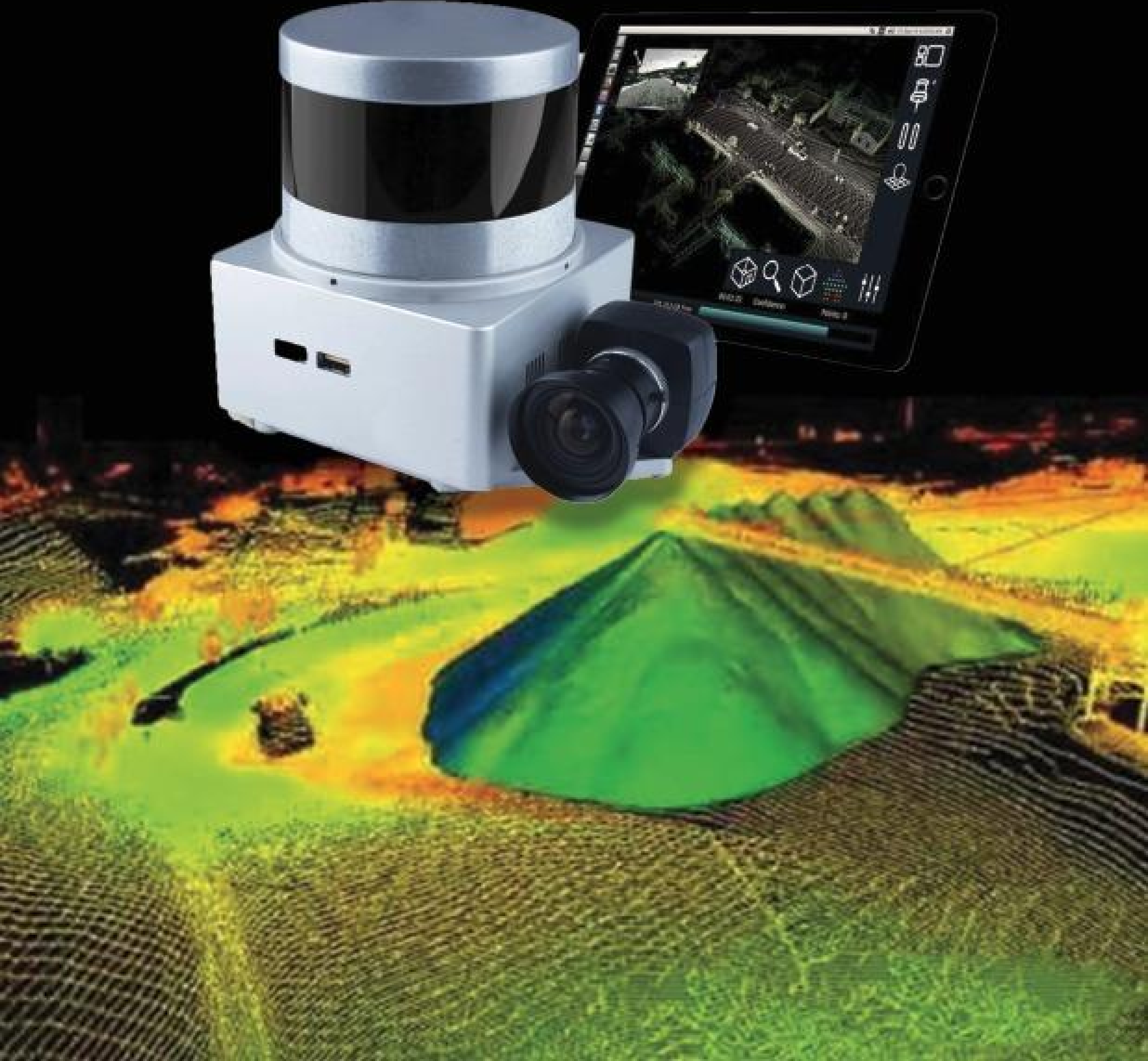

Advanced LiDAR

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- To provide an easily accessible and wide-ranging discussion environment that will strengthen and accelerate the sharing of knowledge and experience between scientists, researchers, engineers, and other practitioners who are involved in direct or indirect activities with the following topics.
- To contribute to the initiation and development of inter-institutional cooperation with LiDAR technology, which is of great importance in solving problems related to professional developments that can play a role in technological and economic development in the world and in Turkey.

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Contents

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Detection of Informal Housing and Non-Complıance with Planning Regulations from Maps Produced by Mobile Lidar Technique

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Keywords
Remote sensing,
Mobile Lidar,
Satellite Images,
Informal housing,
GIS,
Building Determination,
Squatter housing.

ABSTRACT

With the increasing population, cities are constantly changing and developing. Therefore, it is difficult to monitor and control rapid changes in cities. Therefore, planning is very important in terms of controlling these dynamic cities and ensuring regular and planned settlements. However, buildings may not always be built in accordance with the plan and may be built against the zoning law. These structures, which are built against the plan, can distort the city's silhouette, cause unplanned construction and restrict people's access to some services. It is also important that the building detection process, which is needed in many areas from population movements to city development, from illegal building surveillance to casting extraction, is accurate and automatic. With the development of Remote Sensing and Geographic Information Systems (GIS), new methods have been used to detect such structures. One of these methods used is the detection of these structures with high resolution data. In this research, the building detection by using point clouds data obtained from Light Detection and Ranging (LiDAR) system with satellite images.

1. INTRODUCTION

Since the first settled life, people have given importance to city planning due to many different factors. In the first city life, due to both under population and wars with other communities, city plans were made in such a way that people were together as much as possible. However, when we come to the present day, people have changed their city plans due to the increasing population, the wars are almost over and the needs of people have changed. For all these reasons, cities are planned by considering factors such as people's comfort and safety against natural disasters.

However, although it is prohibited, the number of buildings that do not comply with the areas outside the city planning or the rules specified in the plan is increasing rapidly with the increasing population. The detection, inspection and control of these structures is very difficult and costly due to the lack of authorized personnel and supervision, in addition, it causes a loss of time.

However, with the high resolution data obtained by remote sensing methods, it is possible to map very large areas in a much shorter time. These created maps provide the opportunity to analyze in GIS environment with the help of satellite images produced with the help of remote sensing methods or orthophoto images created with aerial photographs.

In this study, it is aimed to monitor the urban development of the building data obtained with the help of mobile Lidar data of Konya province of Turkey, with the help of high resolution satellite data, and to determine the illegal structures and the buildings and areas.

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1.1. Terminology

Informal housing refers to urban settlement that does not conform.

2. INFORMAL HOUSING IN TURKEY

2.1. What is Informal Housing?

Informal housing: Includes informal housing built on government or private land that is used illegally. In such a case, there is no legal claim on the land or the structure built on the land. (Iban, 2020)

Non-compliance with planning regulations: In such a case, most of the owners have a legal claim to the land/structure they built; however, their structures are non-compliant with planning and building laws. This implies that the owners build without, or in excess of, a planning, building, occupancy or functional permit. (Iban, 2020)

When viewed in this way; It will be seen that many buildings in our country can be considered as illegal structures. In addition, in many buildings constructed in accordance with the provisions of the zoning plans, occupancy permits cannot be obtained because of the construction contrary to the project and its annexes, and residences with a construction permit emerge. In this case, it can be said that a significant part of the buildings in the country are unhealthy, illegal, unlicensed or only have construction permits and have illegal elements other than the project requirements required for a residence permit. Buildings of this nature are one of the biggest reasons why natural disasters such as floods and landslides that have occurred in our country recently are so destructive.

2.2. Historical framework of informal urbanisation policies in Turkey

Turkey, after 2. world war, experienced the liberalisation of trade and introduction of gasoline-powered agricultural machines. Government at that time made highly leveraged commercial and industrial investments in major Turkish cities; as a consequence, the Turkish urbanisation began to grow rapidly through that decade. The urban population continuously increased until the 1980s due to massive ruralto- urban migration. Nevertheless, neither housing supplies nor technical infrastructure in the cities were adequate in terms of quality and quantity. As a result, low-income migrating groups were obliged to build squatter houses (mainly on public lands) to meet their housing needs. (Iban, 2020)

"Informal housing, which started for shelter purposes, changed its quality especially after 1980 and became an alternative sector with the motive of grabbing a share from urban rents. "(Iban, 2020)

Informal housing has become a social problem and has become widespread in all sectors in a situation that has diversified from luxury housing, shopping mall, industry, agriculture and tourism structures over time. (Iban, 2020)

2.3. Consequences of Informal Housing

- Unhealthy residential areas and cities are formed.
- It makes it necessary to make a plan.
- It causes the unjustified seizure of state lands.
- It provides resources to the informal economy.
- It negatively affects security.
- Infrastructure, education and health care problems arise.

In summary, the result of this situation: zoning amnesties for unhealthy, unqualified and unsafe buildings have been developed, resulting in intensive structuring with improvement zoning plans.

3. ZONING LAW NO. 3194 (09.05.1985)

Zoning literally means to improve, develop and beautify. A general definition; It is the determination of supply within the framework of certain scales.

It does this by dividing the land that constitutes the legal domain of municipalities, allowing certain land uses to shape the settlement of provinces and districts in certain areas and enable various development plans. (The World Bank)

4. Why is zoning necessary?

The purpose of zoning is to allow states to regulate and control the land and real estate markets. Zoning can also provide an opportunity to stimulate or slow development in certain areas. (The World Bank)

City planning is important for people to live in a more comfortable, safer and more socially developed city. While planning, how and how much a city will grow in the long run are also taken into account, thus paving the way for business opportunities for people.

4.1. Aim & Extent

This Law covers the constructions in the settlements; The plan has been arranged in order to ensure its formation in accordance with science, health and environmental conditions.

Plans to be made and all official and private structures to be built in places within and outside the borders of the municipality and adjacent areas are subject to the provisions of this Law.

5. METHOD

5.1. Informal Housing or Building Contrary to Zoning Legislation

Informal housing or a building in violation of the zoning legislation means a structure that is built without the knowledge of the competent authorities (without a license) or that is built in violation of the license and its annexes by not complying with the obligatory rules in the zoning legislation.(Fig.1) According to the definition in the law; Buildings in violation of zoning legislation, unlicensed buildings, license and its annexes, rules of science and health, floor order, floor area, neighbor distances, zoning road, front line, building depth, zoning principles, and roads in neighboring parcels or zoning plans, It is defined as structures that encroach on areas reserved for public services and facilities such as green areas, parking lots, and are built in places with a definite construction ban.

"It is a common situation that buildings are built contrary to the legislation regulating zoning and construction works by ignoring the rules set by the administration during zoning activities. On the occasion of October 6, World HABITAT Day, the UN announced that one out of every six people in the world lives in slums with unhealthy, inadequate infrastructure and poor property rights. "(Gök H, 2010)

This study aims to detect the structures that are contrary to zoning with the help of high resolution data. The study consists of 3 main stages. In the first stage, the numerical data to be used for the determination of the buildings belonging to the region were obtained with the help of mobile lidar. These data were then transferred to Netcad 8.5 GIS program. The building data obtained in the second stage were matched with the current zoning plan of the province of Konya. In the last step, as seen in figure 1 the resulting data was superimposed on the high-resolution current google satellite image, then this dataset was analyzed and the structures against the zoning were detected.

Figure 1. Example illegal structures on the zoning roads

5.2. Building Data Generated with the Help of Mobile Lidar

Various detection systems have been developed in order to meet the rapidly increasing need for geographic information today. One of them is the Lidar (Light detection and ranging) system, which has become popular especially in the last ten years. (Ekercin & Üstün, 2004) Lidar is a popular remote sensing method used to measure the exact distance of an object on the earth's surface. According to the American Geological Institute, LiDAR uses a pulsed laser to calculate an object's variable distances to the earth's surface. These light pulses produce precise 3D information about the earth's surface and the target object. A Lidar device has three main components; scanner, laser and GPS receiver. Other elements that play a vital role in data collection and analysis are the photodetector and optics. Helicopters, UAVs and airplanes are mostly used to obtain lidar data. In this study, building data obtained from mobile lidar data were obtained from necessary persons and institutions. (Fig.2)

Figure 2. High Speed, High Performance & Dual Browser Mobile Mapping System RIEGL VMX-450 (courtesy Koyuncu Lidar)

We generate the building data with the help of the point data in Figure 3-4. After structure data has been generated and boundaries had been plottered and connected by using the CAD software (Fig. 5).

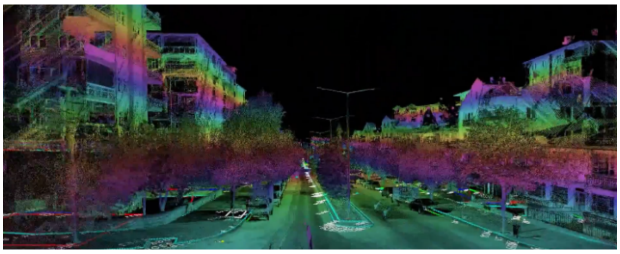

Figure 3. Mobile lidar point cloud data.

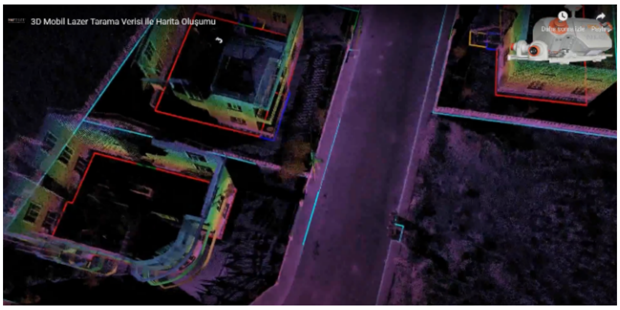

Figure 4. Building data and ownership boundary generated with the help of point cloud data.

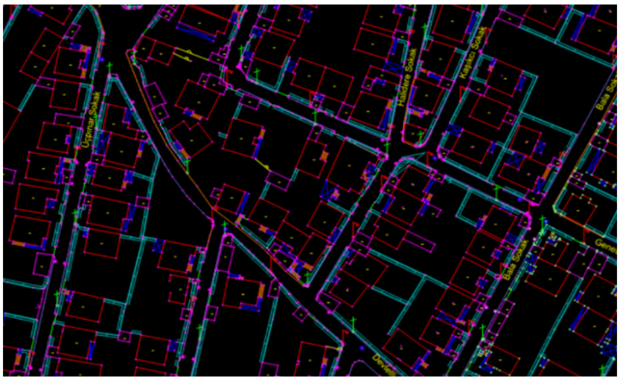

Figure 5. Structure data generated after the drawing step shown in Figure 4.

5.3. Zoning Plan Data

The documents containing the detailed plans and maps of the areas open to development are called zoning. The zoning status gives detailed information about how many buildings can be built on a plot and for what purpose. It's 1/1000 scale plans. (Fig.6). The zoning plan of our study area was taken and the necessary projection definition was made in order to be compatible with other data.

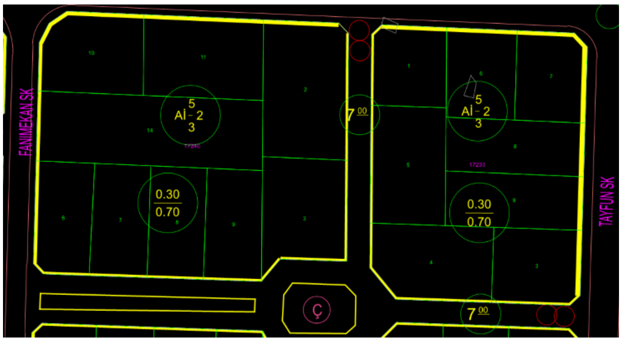

Figure 6. Parceled zoning islands.

5.4. Building Data and Zoning Plan Merging Process

At this stage, the building data created with the help of mobile lidar was combined with the zoning plan layer after the necessary coordinate transformation was made in the Netcad 8.5 GIS program. (Fig.7)

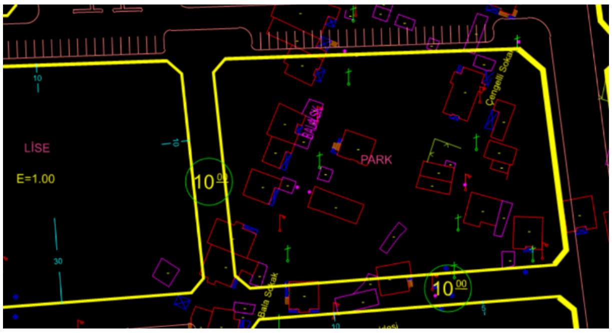

Figure 7. Merging of building data and zoning plan data.

5.5. Leakage build Detection with High Resolution Satellite Imagery.

High resolution current google satellite image was added on the data seen in Figure 7 and the data were analyzed. (Fig.8-12)

Figure 8. Illegal structures on the zoning road.

Figure 9. Buildings contrary to zoning in the school area.

Figure 10. Illegal structures in roads and parking areas.

6. CONCLUSIONS

In this study, as seen in Figure 8, Figure 9 and Figure 10, using lidar data and satellite images, it was revealed that some buildings in the Ladikli, Hacı İsa Efendi, Arifbilge and Batı Hadimi neighborhoods of Meram district of Konya were built against the zoning plan. However, as can be seen in figures 11 and 12, it was revealed that some of the buildings identified with the help of current satellite images used in the study were demolished by the necessary authorities and suitable structures were built in their places.

Figure 11. Demolition of illegal structures.
NOTE: Red areas represent pre-existing buildings.

Figure 12. Buildings built in accordance with zoning instead of buildings constructed in violation of zoning.
NOTE: Red areas represent pre-existing buildings.

7. DISCUSSION

These detected structures only ensured the detection of structures that encroached on areas reserved for public services and facilities such as roads, green areas, parking lots in the zoning plans, and were built in places with a definite construction ban. Apart from this, conditions such as license status, floor and order, floor area and neighbor distances should be examined separately.

The detection of these structures and the measures to be taken afterwards are extremely important for human life. Because the recent flood events, natural disasters such as landslides generally affect the structures built against the zoning law very seriously and can cost human life. In addition, since the identified buildings distort the silhouette of the city and cause distorted settlement, such studies should be accelerated and necessary steps should be taken as soon as possible so that the people of the city can live in a more prosperous environment.

In addition, the building data produced with the help of mobile lidar technology used in this study can be used in 3D cadastre and 3D zoning projects in the coming years.

THANKS

I would like to thank Koyuncu Lidar Map and Engineering Company for their assistance in obtaining the necessary Lidar data for this study.

Author contributions

The authors contributed equally.

Conflicts of interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

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

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Research Article
2022: 2(2); 36-47

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Analytical Documentation of Stone Material Deteriorations on Facades with Terrestrial Laser Scanning and Photogrammetric Methods: Case Study of Şanlıurfa Kışla Mosque

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Keywords
Photogrammetric,
Terrestrial Laser Scanning,
Orthophoto,
Material Deterioration,
Stone Material.

ABSTRACT

Şanlıurfa Kışla Mosque, in its geographical context, is of great importance with its historical importance and architectural features as it reflects the tangible and intangible cultural heritage. However, it is seen that the structure is worn out due to various factors and is exposed to various material problems. In terms of the continuity of the cultural heritage, it is necessary to determine the material problems before the destruction of the building, to document it and to take precautions for protection. The aim of the study in this context is to detect and analytically document the material deterioration on the facades of Şanlıurfa Kışla Mosque. As a method in the study; observational detection and terrestrial laser scanning technique were used. The results of the study support the fact that the method used provides great savings in terms of time and effort in the production of architectural drawings and damage maps, which is the result obtained in many studies in the literature. In addition, as a result of the study, it was determined that the most common type of material deterioration in the building was surface pollution. In the geographical context determined by the study, it is expected to detect the dangers related to stone structures and to take measures to prevent the hazards related to the structures.

1. INTRODUCTION

Stone structures form a large part of the cultural heritage in the world. Many historical structures such as the ancient city walls in China and the monumental structures in Europe are made of stone materials. However, stone materials expose to deteriorations today due to various factors and the structures encounter the risk of extinction (Alptekin et al., 2019; Karataş,2016; 2022; Karataş et al., 2022; Kanun et al.,2022; Shen et al., 2019; Yakar & Alptekin, 2021). When the studies, which investigate the causes of deteriorations of the stone structures in the world, are reviewed in the literature, it is emphasized that recently the factors arising from the air pollution mostly cause stone material deterioration (Ambrosini et al., 2019; Corvo et al., 2010; Comite et al., 2017; Comite et al., 2020; Falchi et al., 2019; Gibeaux et al., 2018; Graue et al., 2013; Ivaskova et al., 2015; Rovella et al., 2020; Vidorni et al., 2019; Vidal et al., 2018; Webb et al.,1992). The common point of these studies is the highlighting on the requirement of conducting studies to identify the deterioration factors, to which the stone structures expose mostly within the geographic context in different countries, and thus to determine the factors, of which the cultural heritage of the world is under the threat. Based on these requirements emphasized in the literature, investigations have been carried out on stone structures in different countries. In the studies conducted in Havana, Cuba and San Francisco, Mexico cities, it was concluded that atmospheric deterioration of the stone was intensified with the impacts on the appearance and integrity of valuable historic buildings,

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which have been built by using limestone, due to air pollution and humidity (Corvo et al., 2010). Another example conducted by Ivaskova et al. (2015) documented that the factors such as the climate parameters and atmospheric pollution became a serious problem increasingly not only in Slovakia, but also in the whole world, and the air pollution causes a great deterioration effect on the stone materials in the Republic of Slovakia. Rovella et al. (2020) determined that the vehicle traffic and the industrial activities, which are the main contaminant resources in Cairo, are the greatest deterioration causes on the stone structures. In the study conducted by Arroyo et al. (2013) on the stone structures in Naples city, it was suggested that the compound of materials and mortars used in the restorations carried out on these structures previously are sulphate-rich, and the use of this faulty material is the greatest cause of deterioration on the stone structures in Naples city. Comite et al. (2020) emphasize the importance of the impact of local sources of pollution on the cultural heritage in Italian and European cities. Another deterioration cause that is emphasized is the fact that the rate of stone deterioration related with the "memory effect of construction stones" also depends on the environmental conditions, to which the stone exposed in the past (Vleugels et al., 1993).

As emphasized also in the studies explained above, it is important to reveal and document the stone material problems and causes of deterioration, within the context of identifying the deterioration factors, to which the stone structures expose mostly within the geographic context in different countries, and thus determining the factors, of which the cultural heritage, which constitutes the stone structures in the world, is under the threat. Documentation is a valuable tool to preserve the heritage resources. However, manual methods are time-consuming and troublesome in the procedure of documenting the material problems.

Today, there have been many innovations in the documentation of the cultural heritage with the developing technology, modern documentation techniques have advanced rapidly, and the data obtained from the methods such as terrestrial laser scanning and photogrammetry started to be used as base in the documentation of the material deteriorations. Traditional methods used in the documentation of material deterioration in historical buildings are inadequate in terms of time and effort today (Barber et al.,2006). In studies in the literature; It is emphasized that the use of terrestrial laser scanning methods, instead of traditional methods that require long and laborious measurements, brings great convenience, especially in the documentation and evaluation of stone surfaces. When the studies are examined, it is seen that the analytical drawings required to document material deteriorations can be obtained easily and in a very short time frame by using the terrestrial laser scanning method (Alptekin et al.,2019; Alyilmaz,2010; Burgerb et al.,2007; Casula et al.,2009; Curso et al. .,2017; Darap et al.,2007; Ercoli et al.,2013; Fais et al.,2017; González et al., 2010; Karataş et al.,2022; Kottke et al.,2011; Korumaza et al.,2010; Yakar et al.,2015; Meroño et al.,2015; Pozo et al.,2016; Willis & Sui,2010; Pesci et al., 2011; Ulvi et al.,2016; Tutzauer & Haala (2015); Şasi. & Yakar, 2017; Ulvi & Yakar,2010; Yakar et al.,2009; Yakar et al.,2015; Yakar & Mirdan, 2017; Yakar & Dogan, 2019; Yakar & Omar ,2016; Yakar, 2015; Yılmaz, & Yakar, 2006; Schnabel et al., 2010 ; Quagliarini et al.,2017). An important example is the study of Corso et al. (2017); which combined the image layers obtained from terrestrial laser technology with the data obtained from on-site examination in order to diagnose the material deteriorations of stone facades. As a result of the study, it is verified that the degradation patterns such as surface roughness, stone relief, stone erosion or change, color change on the stone can be easily detected with the method used.

Another technique that is widely used in the literature for the documentation of material deterioration of stone structures; These are the studies that obtain the data that will be the basis for creating orthophotos by transferring the data obtained from terrestrial laser scanning to various software and defining the types of material deterioration over them. Orthophoto image; They are digital images in which errors caused by curvature, rotation and height difference are corrected and made into vertical projections.

Many studies in the literature confirm that orthophoto images, which can be created with various software, are very useful data for architectural documentation, thanks to point clouds obtained from laser scanning data. In these studies, it is confirmed that thematic maps can be obtained by utilizing orthophotos with a three-dimensional model obtained with terrestrial laser scanning data (Mol et al., 2020; Stober et al., 2018; Gabriele et al., 2010; Meroño et al., 2015; Comert et al., 2012; Yılmaz and Yakar 2006).

It is also suggested in various studies that the use of orthophotos obtained by photogrammetric methods is practicable in the documentation of material problems. In a significant example, in which the orthophotos are used to document Roman amphitheatre in the centre of Amman, its surrounding and its material problems, it was enabled to digitise all important spatial information for the site with the orthophotos (Rawashdeh, 2013). Another study conducted by Widartono & Fitri (2016) has mapped the areas of Ijo temple complex using orthophoto images and suggested that orthophoto image maps can be used as base in the documentation of material problems and building. Perfetti et al. (2019) revealed that to produce the architectural drawings (sections and plans) with the production of orthophotos obtained via the photogrammetric methods from the data in laser scanning is sufficient. Yilmaz et al. (2007) emphasize the superior aspects of photogrammetry in restoration projects, compared to the traditional methods, in their study. Furthermore, he suggests that the orthophoto images obtained from the digital and 3D data via photogrammetry provide the information required for documentation, and besides these methods are easier, more precise, and enables saving of time in scaled drawing projects and in the determination of material problems, when compared with the classic methods. In the study, the facade drawings and 3-dimensional model of the building could be completed using numeric short-distance photogrammetry, and it was determined that digital short-distance photogrammetry makes contribution to the scaled drawing, zoning and restoration projects.

In addition, in the literature the computerized methods and short-distance photogrammetry are recommended as a preventive method that enables us to determine, measure and monitor the time wise evolution of some structural problems (Arias et al., 2005)

As specified previously, in the literature it is emphasized that it is necessary to conduct studies to identify the deterioration factors, to which the stone structures expose mostly within the geographic context in different countries, and to determine the factors, of which the cultural heritage of the world is under the threat. Within this context, the aim of this study is to produce orthophotographs from the data obtained by terrestrial laser scanning with the photogrammetric methods, and to document the facade drawings and the material deteriorations occurring on the facades analytically with the method of using the produced orthophotographs as base. It is expected that measures shall increase in the future to prevent the danger regarding the structures, with the determination of the dangers regarding the stone structures within the geographic context, which were found with the study conducted.

1.1. Location of the Building

The building is located in the centre of Şanlıurfa Viranşehir County, Kışla Neighbourhood(Figure 1).

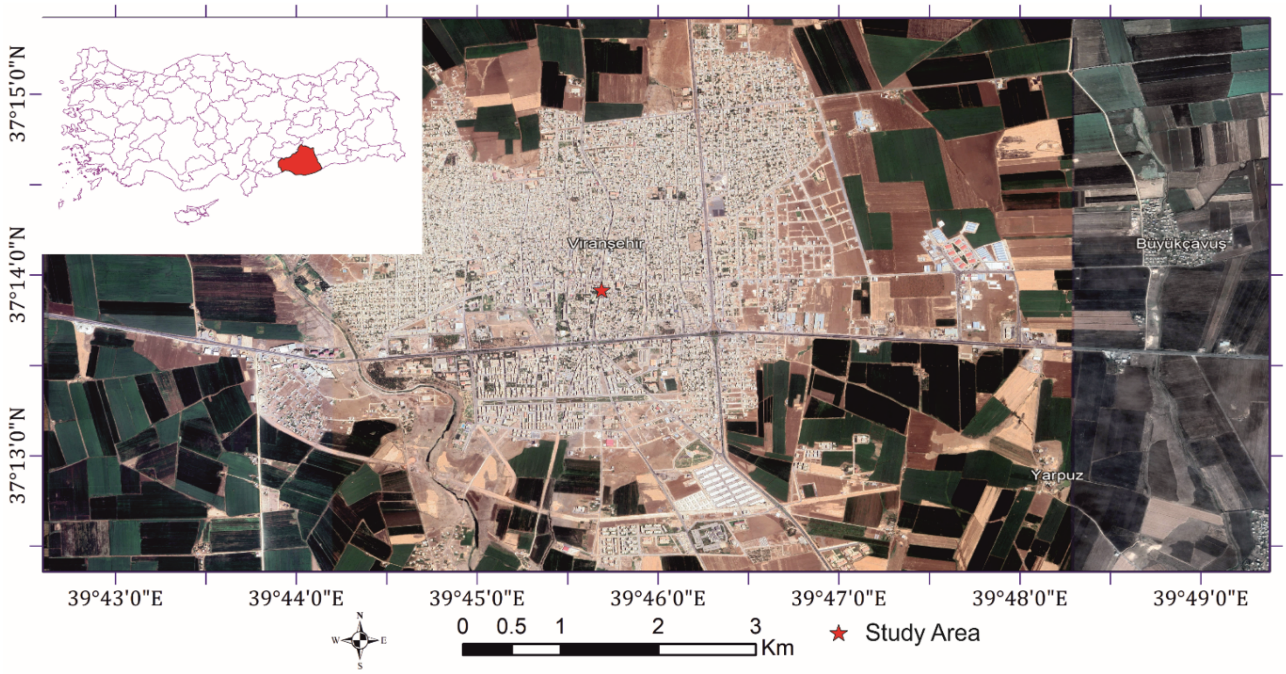

Figure 1. Location of Şanlıurfa Kışla Mosque

1.2. History and Architectural Analysis of the Building

The year of construction of the Mosque is not known. However, it is estimated that the building was built at the end of XIX. century. The epigraph dated H.1343\M.1923 located on the east frontage of the bedplate of the minaret is an epitaph. In addition to this, the epigraph placed within the mosque is undated, and related with the extension of the mosque.

The mosque was built from smooth cut stones and in rectangular plan with pole covers. Cover system was transformed into flat reinforced concrete roof in recent years. Recently, a narthex and women's gathering place were added to the front side of the mosque. The muezzin gathering place, which extends along the North wall, in the direction of entrance within the sanctuary, was made of wood and settles on two columns on the front side. The mihrab has round niche and made of cut stone, and its mimbar is made of wood. The minaret, which is located in northwest, was made of cut stone and has a minaret balcony with stalactite. The guardrail of the minaret balcony is iron.

Kışla Mosque is within the mosque group, which has single plate parallel to the mihrab and pole covers. The Mosque is consisted of the narthex placed on the North entrance section and of the upper gathering place and sanctuary placed above it. The minaret rises above the reinforced concrete flat roof on the northeast of the building. The mihrab is placed on the middle axe of mosque's South wall, and the mimbar is placed just on the west of it. The mihrab, which has a round niche and made of cut stone, and the wooden mimbar has been left as far as plain and without ornaments.

WC and lodging are located on the northwest; muezzin lodging, depot, building of Quran Course and the lodging on its first floor are located on the north of Kışla Mosques, which is shaped with the courtyard and its surrounding units. Shadirvan is located on the front side of mosque's east frontage. In addition, the section of burial area (reserved for special people) is located on the southwest of Kışla Mosque.

2. METHOD

The material deterioration of the facades of the building determined in the study was carried out with a literature search on the original state of the building in the first stage to create analytical surveys.

In the next stage, in order to understand the current situation of the building, the material deteriorations on the facades were determined by making observations. The determined material deteriorations were classified according to the structural elements of the stone structures and recorded in the table prepared in order to represent the material deteriorations in a systematic way. The prepared schedule is explained in section 2.2 (Table 1).

In the next stage of the study, a laser scanning device (Faro Focus Laser Scanner) was used in the part of the building's facades in order to obtain images of the facades of the building and point clouds were obtained during the scanning. Objects up to 330 meters away can be scanned with the device used (see Figure 2).

Figure 2. Laser Scanner (The Focus3D X 330)

The obtained data were processed in the PointCab Origins 3.9 program and scaled orthophotos (upright photo) of the building facades were obtained. Orthophoto image are the numerical images, which the errors arising due to the inclination, toe and height differences are rectified and transformed into vertical projections.

Orthophoto images, which may be formed through various software, thanks to the point clouds obtained from laser scanning data, are very useful products for architectural documentation. Since the orthophoto images obtained are scaled, identical images of the structures may be obtained. Therefore, ortophoto images can be used as base in architectural drawings. The orthophoto images obtained from the points clouds enable to make measurements on the plans and sections with millimetric precision in office environment (Comert et al., 2012; Ulvi and Yakar 2014; Alptekin and Yakar 2020).

Analytical survey drawings were obtained by using scaled orthophotos of the facades obtained. Section 2.2 on the analytical survey drawings obtained. The stone material deterioration types detected in the study were analyzed analytically. The figure below summarizes the situation regarding the workflow of the work done (Figure 3).

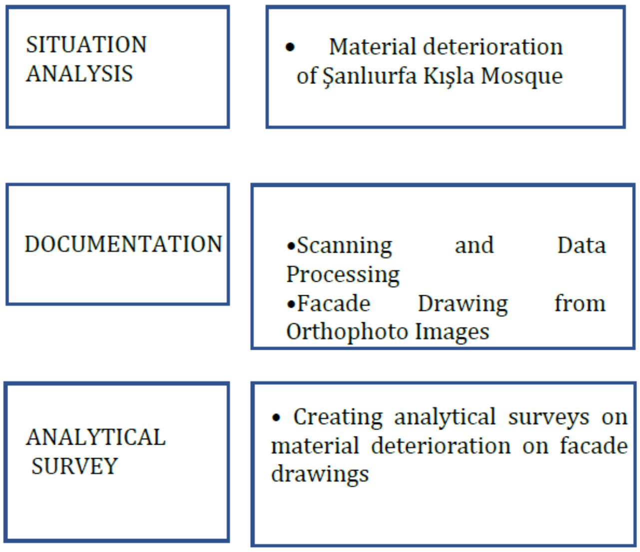

Figure 3. Workflow showing recommended process for orthophoto generation and integration from terrestrial laser scan data in documenting material deterioration

2.1. Situation Analysis

In order to understand the relationship of the building with its environment before making conservation proposals for the building, it is necessary to conduct research on the building in terms of its general structure, form, material and environment (Karkaş and Özgünler, 2021). All information about the historical documents about the building, its changes over time and material deterioration in the current situation were collected.

2.2. Determination of Material Problems

In this stage, within the first step of evaluating the conservation status of the building, an observational investigation, which is consisted of damage mapping, was carried out. Stone material deteriorations occurred on the facades of the Mosque were explained in ''Table 1.''.

Table 1. Stone material deteriorations on the facades of Kışla Mosque

NATURAL STONE CONSTRUCTION ELEMENTS				PROBLEMS ENCOUNTERED ON CONSTRUCTION ELEMENTS MADE OF MASONRY MATERIAL IN BURDUR STATION PREMISES																		Faulty Repairs		
				Loss of surface	Fragmentation	Formation of gap/ hole	Pitting	Cracks	Spalling	Foliation	Discharge of jointing	Surface contamination	Shell formation	Efflorescence	Crystallization	Formation of plant	Formation of moss	Corrosion (Rust stain)	Tear	Loss of form	Colour change	Use of cement	Fall of plaster	Other
VERTICAL BEARINGS	SINGLE BEARINGS	Leg		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Column		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	CONTINUOUS BEARINGS	Wall		X	-	-	-	-	-	-	-	X	-	-	-	X	-	-	-	-	-	X	X	X
HORIZONTAL BEARINGS	FLOORINGS	Flat		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Curvilinear -		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WALL OPENINGS		Window	Lintel/jamb	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Sill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Door	Lintel/jamb	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Sill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-
		Arch		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AUXILIARY ELEMENTS		Network																						
		Moulding																						
		Gargoyle																						
		Chimney																						
		Element for passage to the cover																						

2.3. Scanning Procedure and Data Processing

Terrestrial laser scanning method was used in scanning procedure in this stage, in order to document the building as 3-dimensional. Exterior facade scanning was carried out by using laser scanning device (Faro Focus Laser Scanner), and point cloud of the building was obtained in the scanning procedure ("Fig. 4").

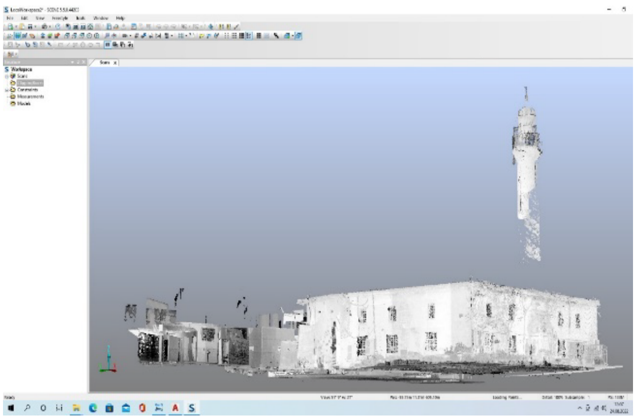

Figure 4. Point cloud obtained regarding the building

2.4. Obtaining the Orthophotograph Images

In this stage, orthophotograph images of the building were obtained from the point clouds obtained in the laser scanning procedure in the software named PointCab Origins 3.9 ("Fig. 5-11").

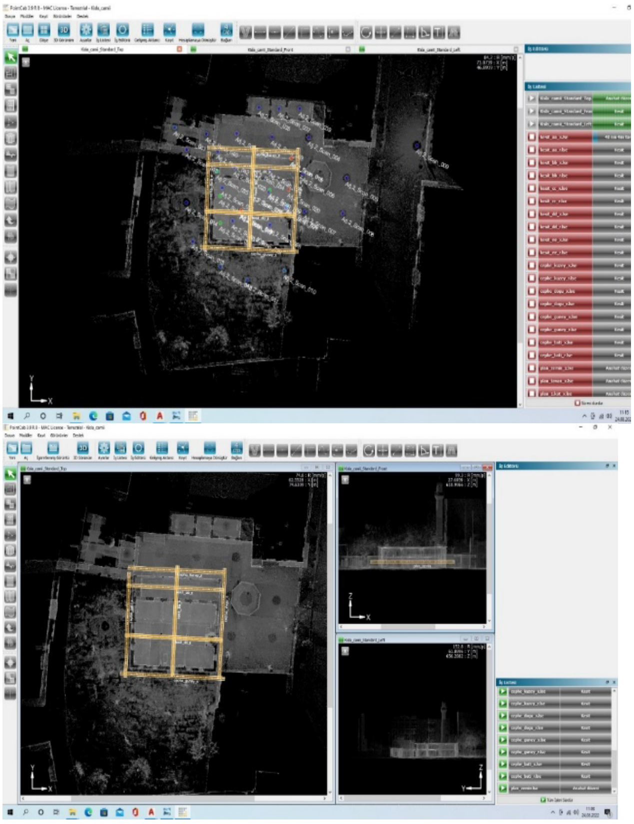

Figure 5. Scene of creating orthophotographs from the point cloud obtained from Terrestrial Laser Scanning, using the programme named PointCab Origins 3.9

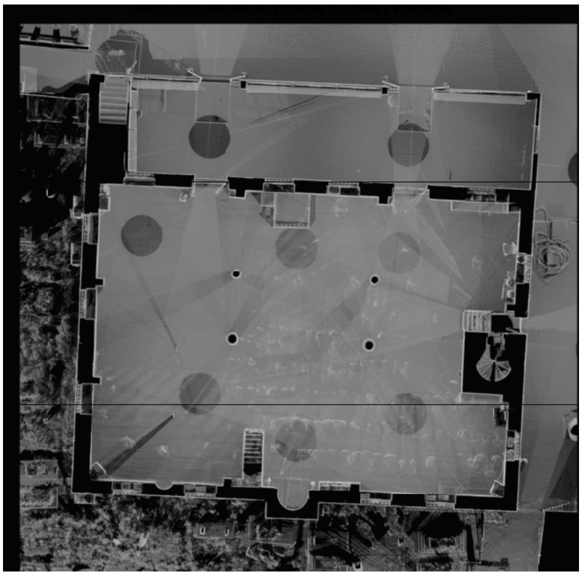

Figure 6. Orthophoto of layout plan

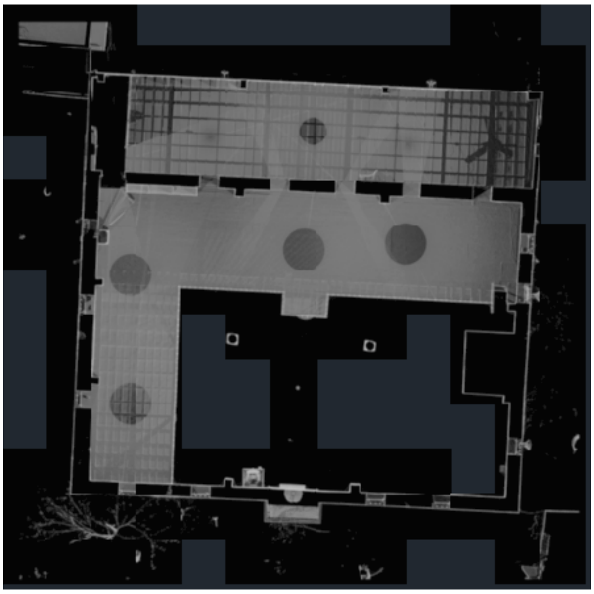

Figure 7. Orthophoto of ground floor plan

Figure 8. Orthophoto of west frontage

Figure 9. Orthophoto of east frontage

Figure 10. Orthophoto of south frontage

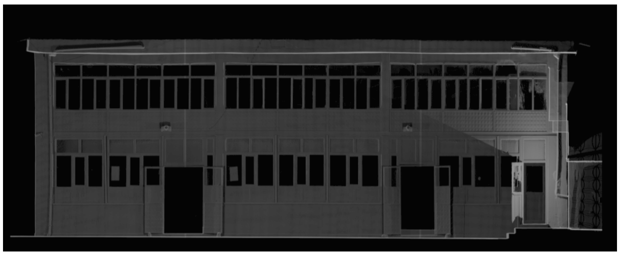

Figure 11. Orthophoto of north frontage

AutoCAD programme was used in the procedure of creating the drawings of the facades. Before commencing the drawing procedure, the orthophotograph images produced in the software named PointCab Origins 4.0 were transferred to AutoCAD environment. They can be transferred into AutoCAD media in the format of TİF file with tif. or .tiff extension, which is the common data format of AutoCAD software. Facade drawings of the building were obtained through AutoCAD programme, using the scaled orthophoto images obtained.

3. RESULTS

3.1. Documentation of Material Deteriorations on the Facades

When the facades are investigated, it is seen that the most frequent material deterioration seen is the surface contamination depending on the air pollution. This problem is followed by intervention with mortar, mossing, material loss, deformation, plaster and paint spalling, and cracks respectively from most to least ("Fig. 12").

Figure 12. Legend regarding the material damage layouts

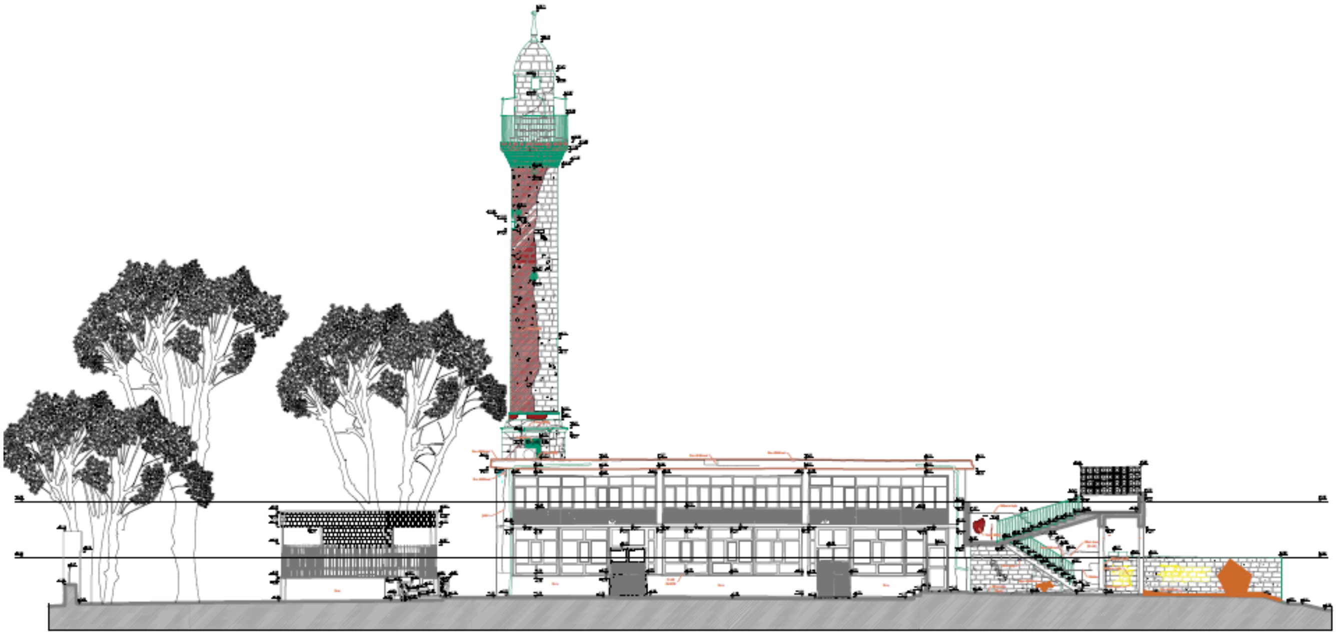

Figure 13. North frontage material damage layout

Plaster spalling, cracks, material loss, surface contamination, deformation, paint spalling were found on the north frontage (''Fig. 13'').

Intense deteriorations were observed on the South frontage and deformation, intervention with mortar and mossing problems are seen. Although there is interventions with cement-added mortar partly on the stone surfaces close to the ground elevation, as well as surface contaminations are seen (''Fig. 13'').

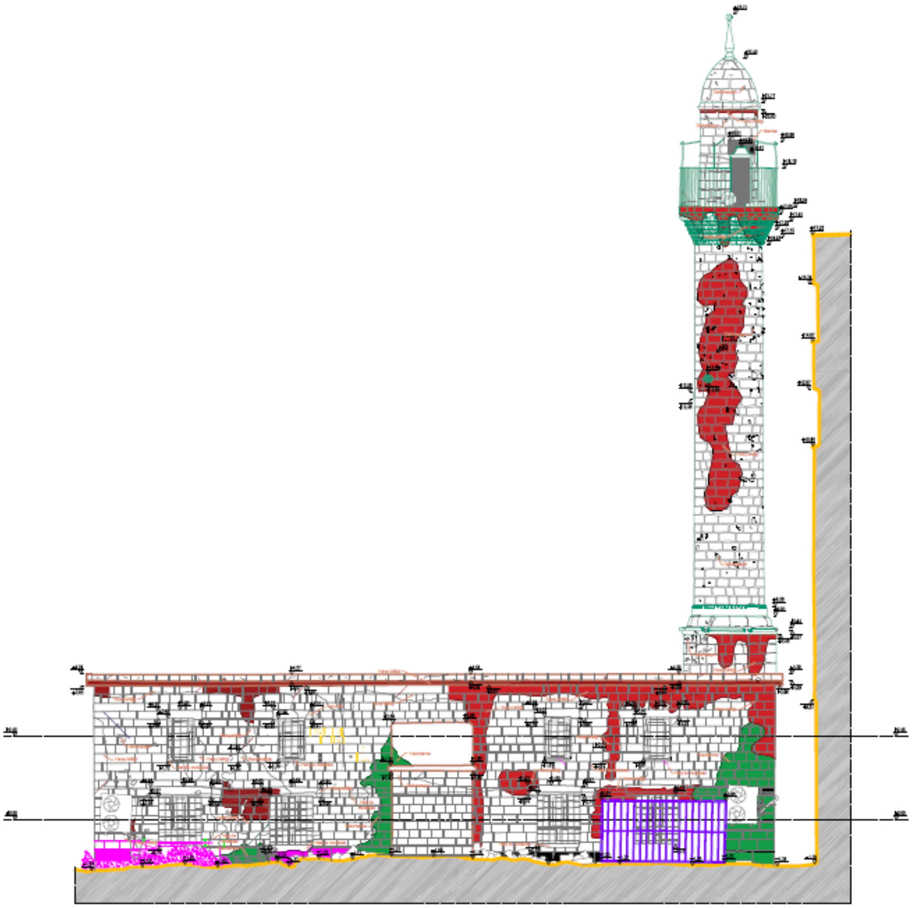

Figure 14. South frontage material damage layout

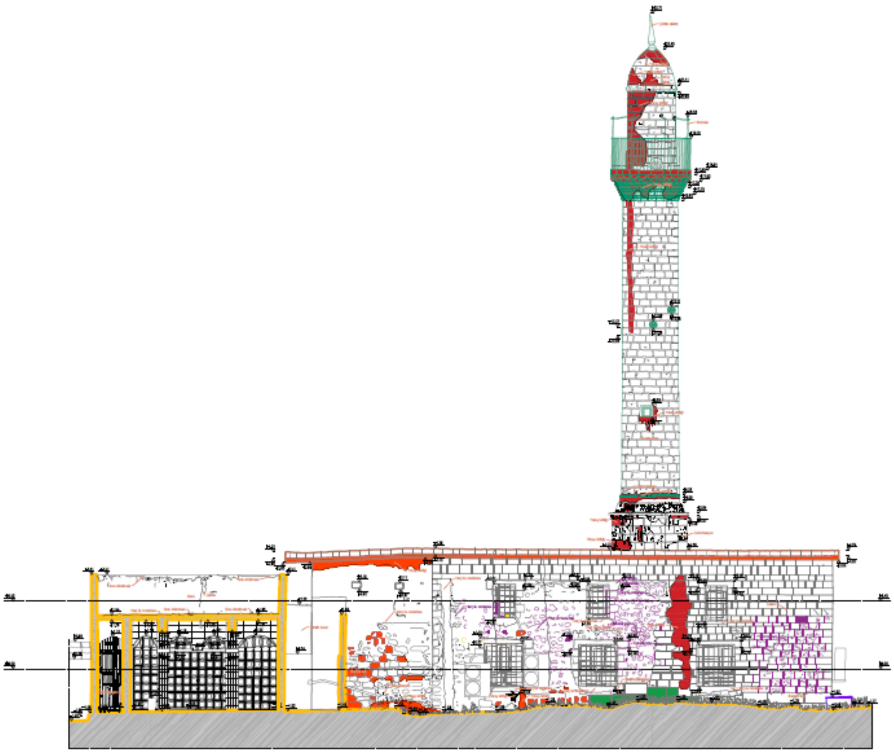

Figure 15. West frontage material damage layout

Problems of deformation, plaster spalling, intervention with mortar, surface contamination, material loss, mossing, and cracks were found on the west frontage. Intense surface contaminations, primarily the material losses, wear and fractions on the stone surface were observed (''Fig. 13'').

Intense deteriorations were observed on cut stone and basalt stone surfaces on the facade located on the east frontage, and problems of surface contamination, deformation, cracks, intervention with mortar, and mossing are seen. Besides, jerry-built attachments such as the electric cables, and sound installations are also present on the facade (''Fig. 13'').

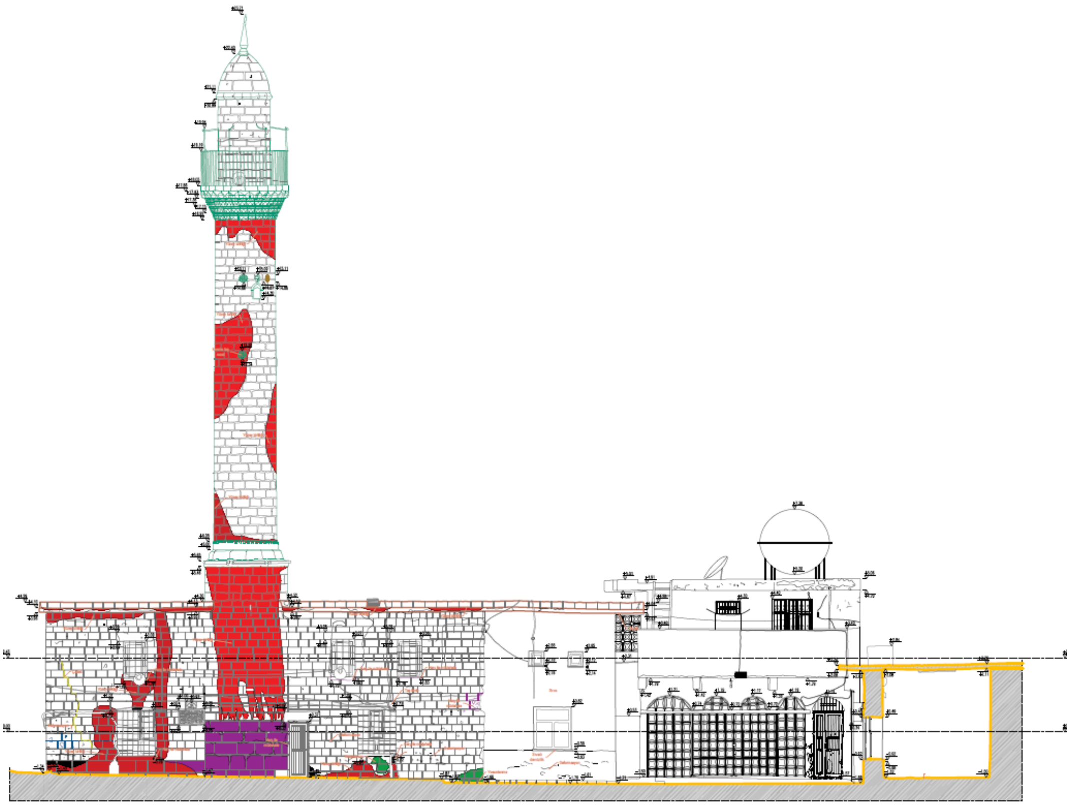

Figure 16. East frontage material damage layout

4. DISCUSSION

The aim of the study is to analytically document the material deteriorations that occur on the facades by combining the data obtained from the observational determination of the building with the data obtained by terrestrial laser scanning. As a result of the study, it has been seen that the terrestrial laser scanning method and the use of orthophoto images can be used as a base in the creation of the drawings of the plans and facades of the building, instead of the traditional methods that require long and laborious measurements, and this method provides great savings in terms of time and effort. This result obtained in the study supports studies showing that it is sufficient to produce architectural drawings (sections and plans) from orthophotos produced from laser scanning data (Comert et al., 2012; Gabriele et al., 2010; Mol et al., 2020; Stober et al., 2018; Meroño et al., 2015; Rawashdeh, 2013; Perfetti et al., 2019; Rawashdeh,2013; Widartono & Fitri Rawashdeh,2013; Widartono & Fitri, 2016; Perfetti et al., 2019).

In addition, when the drawings obtained from the orthophotos and the data obtained from the observational determinations are combined as a result of the study, it is seen that the material damages can be easily mapped. This result; Widartono & Fitri (2016) and Corso et al. (2017), drawings produced from orthophoto images obtained by various methods from terrestrial laser scanning and observational detection data are similar to the results of studies showing that various types of deterioration in the stone facades of structures can be easily mapped.

Another result obtained in the study is that orthophotos obtained from the data obtained by terrestrial laser scanning save time and effort in documenting material problems and architectural documentation. This finding confirms the finding of Yılmaz et al. (2007) that orthophoto images obtained from terrestrial laser scanning data are easier, more precise, and save time compared to classical methods in documenting material problems and architectural drawings.

In the study, it was determined in the findings about which types of material deterioration were seen on the facades of the building; the most common material degradation is surface contamination in the form of a gray layer. This finding in the study supports the finding in the literature that the most common material deterioration in stone structures in the world is surface pollution within the scope of Şanlıurfa Kışla Mosque (Ambrosini et al., 2019; Comite et al., 2017; Comite et al., 2020; Corvo et al., 2010; Falchi et al., 2019; Gibeaux et al., 2018; Graue et al., 2013; Ivaskova et al., 2015; Rovella et al., 2020; Vidorni et al., 2019; Vidal et al., 2018; Webb, 1992).

5. CONCLUSION

In the study, facade drawings were made by using orthophotos produced from the data obtained from terrestrial laser scanning as a base, and material damage maps of the building were obtained by processing the observationally detected material deteriorations on the facades. As a result of the study, it has been determined that the most common material deterioration in stone facades is surface pollution, as in stone structures in many countries. In this context, in order to determine the causes of surface pollution in the building and the source of the dirt (air pollution, traffic, user effects), it is necessary to carry out various experimental researches in the building in subsequent researches.

Once the cause of the surface contamination has been determined, a decision should be made to use either the cleaning technique or the combined techniques. The type of dirt and its relationship with the surface, the correct definition of the stone surface-patina relationship, and the separation of dirt and patina are matters of expertise. In addition, the state of preservation of the stone surface to be cleaned, the construction technique, and the neighboring materials should also be taken into account in the making of the decisions. Different methods should be used for building stone surfaces and decorated stone surfaces, different stone surfaces and impurities. One or more of the techniques such as washing with atomized water, absorbing clays and pulp compression, gels, controlled sandblasting, micro sandblasting, precision mechanical cleaning with small hand tools, laser cleaning should be applied on the test surfaces on the structure, and the surface erosion and the effectiveness of the method should be tested.

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Author contributions

Lale Karataş; Methodology, data collection, writing **Aydın Alptekin;** Control. **Murat Yakar:** Editing the manuscript

Conflicts of interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

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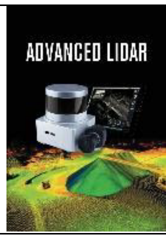

Detection of Road Distress with Mobile Phone LiDAR Sensors

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Keywords
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LiDAR,
Road, ,
Pothole.
Rut.

ABSTRACT

Comfort and safety on urban roads are two important and desirable factors in road transport networks. When it comes to providing road comfort, potholes, which emerge on the road surface for different reasons, are one of the problems that we do not want to encounter in our daily transportation. Although different techniques are already being applied to detect deformations on road surfaces, developments in measurement technologies gradually bring alternative techniques with them. The best example for this are the small size LiDAR sensors which have newly been added to mobile phones, and the subject of this study is whether they can be used in detecting such problems. The data collected from the field survey enabled a detailed examination of the road potholes with the proposed methodology based on region growing and plane fitting. According to the results, the 3D sensor technologies will take a new place in measurement technologies by providing high dense data and visualisations in small-sized projects, thus facilitating instant decisions. In the study, potholes on the road surface were determined with 4 different data sets obtained in Denizli province Pamukkale district Karahayıt neighbourhood and detailed information about their characteristics was collected. As a result, with this study, the LiDAR sensor released to the market by Apple on iPhone 12 and following versions has developed an alternative measurement technique and methodology that can be used in the implementation of small-sized projects on road surfaces. It is clear that the use of mobile phone-based LiDAR sensors in road repair services has significant potential in the near future.

1. INTRODUCTION

Highways undoubtedly play an important role in connecting cities. The geometric standards of the transportation networks and the safety of the road surface ensure that the people using the transportation network have a problem-free and high comfort journey. However, continuous monitoring of highways from planning to a sustainable network design also poses a significant economic burden. Undoubtedly, the Turkish General Directorate of Highways, together with the local administrations, spend a great deal of effort on these issues and always try to keep the road safety at a high level. Testing whether the safety standards of the highways are in place with the traditional methods and classical mapping processes used cause high costs. However, modern technological equipment has become available in order to make such measurements cheap.

Today, it is possible to access technologies that provide dense data with low-budget planning. Although the hardware that can perform light detection and ranging (LiDAR) with laser signals constitutes a significant budget, its reliability in small-scale projects with the required high accuracy with terrestrial and even mobile equipment attracts the attention of researchers (Vosselman & Maas, 2010; Yılmaz & Yakar, 2008). Simultaneously, applying necessary measurements on images with remote sensing, image processing, computer vision and photogrammetric methods, which provide intensive data by using passive sensors and then processing the field data, constitute potential innovative measurement techniques.

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These technologies are not only limited to data supply, but also have the ability to process data instantly thanks to cloud computing. In this way, it has become possible to make necessary analyses even during field surveys. This saves time, reduces the need for labour, and thus provides significant savings in project costs (Gollob, Ritter, Kraßnitzer, Tockner, & Nothdurft, 2021).

Deformations caused for different reasons are observed on highways (Findley et al., 2022). Common road surface deformations; potholes, ruts and cracks (Islam & Tarefder, 2020). On the other hand, the reasons for the deterioration of road surfaces are the pressure exerted by high-tonnage vehicles on the asphalt surfaces, rapid temperature changes, precipitation, infrastructure works and the use of asphalt components that do not comply with the standards.

Considering the different application platforms and purposes in literature, the existence of important studies is substantial (Wang, Heenkenda, & Freeburn, 2022). In particular, the extraction of the surface of highways and the detection of road networks are made with data obtained from satellite imaging techniques, aerial platforms and ground surveys (Li, Ling, Sun, Xu, & Huang, 2019; Wei, Tsai, Chang, & Wang, 2022). The main contribution of this study is the detectability of potholes/collapses on road surfaces with the LiDAR sensor in mobile phones. The methodology and materials applied for this are given in detail in the following sections.

2. METHOD

Two basic data analyses were used in the proposed approach. The first stage is the determination of the application with which the data will be obtained on the mobile phone followed by the detection of the points where the plane detection will be made with the region growing algorithm, the plane fitting process and the determination of the deformations on the road surface.

2.1. Apple Applications

Currently, LiDAR sensor is only integrated on iPhone 12 Pro, 12 Pro Max, 13 Pro, 13 Pro Max, iPad Pro 2020 and iPad Pro 2021 with M1 support (https://www.apple.com/). “Measure” application comes first among the measurement applications. As the name suggests, the Measure app is used for simple measuring operations. It is also very easy to measure the distance between two points and perform the scale operation. Distances can be measured both vertically and horizontally. The measured points remain fixed in the augmented reality (AR) environment.

Besides the given measurements, the app automatically tests and measures rectangles and even automatically calibrates peoples’ height. You can take pictures of these measurements to store the data and share them as images.

Another important application is SiteScape – 3D scanning application. After installing the SiteScape application on the iPhone 12 pro mobile phone, an account must be opened from the SiteScape Application. While a limited number of scans are made free of charge in a certain period of time, an unlimited number of scans can be made after the membership fee and synchronisation with the cloud is made. Detailed information can be found at https://www.sitescape.ai/.

Another widely used application, which is also used in this study, is the 3D Scanner App (https://3dscannerapp.com/). With this application, a 5x5m wide outdoor environment is scanned in a single scan. This feature is a sufficient technical feature for the study carried out in this research. Point clouds can be exported directly in *LAS* file format. Point clouds also contain *RGB* (Red, Green, Blue) radiometric information.

2.2. Ground Image Based Reconstruction

Another method widely used in geosciences to obtain point clouds and to measure on them is a structure from motion (SfM) image processing-based method. Images were obtained with the same Apple iPhone 12 Pro mobile phone and the analyses were processed with Agisoft Metashape software (https://www.agisoft.com/). After obtaining the images using the iPhone, a file format with HEIC extension was encountered. These files were later converted to *JPG* format with the R *magick* package (Ooms, 2021; Team, 2021). In this way, images were transferred into Agisoft software. After the images are imported into the software, the general process flow is aligning images, constructing dense point clouds and a mesh surface model, generating texture, creating digital terrain model and orthomosaic. Other enhanced analyses were performed on point clouds containing the road surface.

2.3. Calculation of Deviations from the Plane

The depth level of the pothole was determined based on the points around the point clouds for each separate test data. For this, the region growing algorithm (Rabbani, Van Den Heuvel, & Vosselmann, 2006; Vo, Truong-Hong, Laefer, & Bertolotto, 2015) was applied first, followed by the plane fitting algorithm. Region growing methods are widely used on basically 2D images (Chang & Li, 1994). It is checked whether the neighbouring pixels determined near a region have similar properties, and if the given criteria are met, the clustering process is applied. The basic principle is to classify a point or pixel by comparison with its neighbours. In this study, 4 points were determined and a plane was created according to the surface points determined by the region growth algorithm of said points. The generated plane and raw point cloud data were evaluated by point-plane comparison.

After the region growing points were determined, the surface normals of the plane were obtained. Given any point P, there is an infinite plane containing the point P. However, if the normal vector of the plane is detected in three-dimensional space (R^3), the plane is defined in this way. Surface normal means the vector perpendicular to the plane.

A point on the plane (red point) and green (surface normal) are given in Fig. 1.

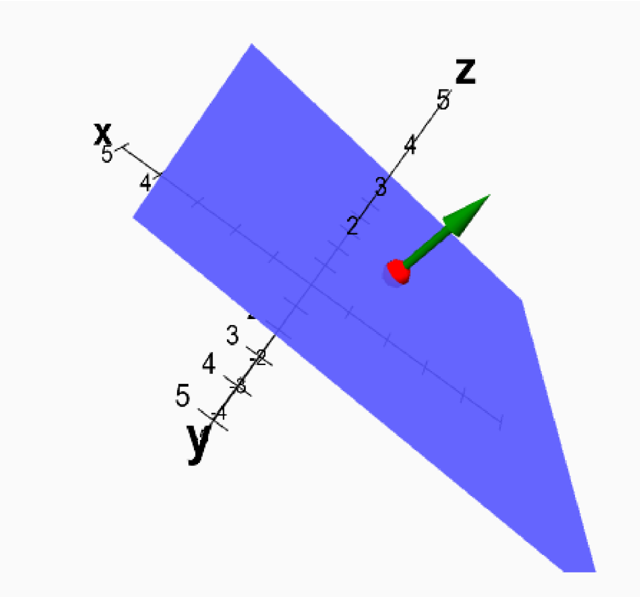

Figure 1. The basic parameters that make up a sample plane are a point in the plane (red dot) and plane surface normal (green arrow)

After the points forming the plane and the plane are determined, the deviations of all points from this plane should be determined. To detect the deviation of a point from the plane, that point must be projected into the plane. That is, the point on the plane must be found. Thus, the distance of the points in the closest perpendicular direction to the plane is found. The distance from any point P to the plane is defined as the length of the projection of the coordinate differences on the surface normal.

It is assumed that the local potholes formed on the road surface do not change much in a small area and are created with a 3D plane model as below (George B. Thomas, Weir, Hass, Heil, & Behn, 2016; Strutz, 2011).

$$Ax + By + Cz + D = 0 \quad (1)$$

where, *A, B, C, D* represent the surface normal parameters. *x,y,z* are point coordinates. The least squares estimation (LSE)(Strutz, 2011) and *A,B,C,D* estimation were made with the *lm* function of the R program (Team, 2021). As mentioned before, with the assumption that the road surface has not changed much and the region growing algorithm, the plane settlement was performed on the points outside the pothole, and thus the depth information of the pothole was obtained.

The distances (*d*) to the plane model given above (Eq.1) were calculated with the following formulas (George B. Thomas et al., 2016).

$$d = v \cdot n \quad (2)$$

$$d = \frac{|Ax1+By1+Cz1|}{\sqrt{A^2+B^2+C^2}} \quad (3)$$

2.4. Test Area

As the study area, 4 road potholes were selected on the 134th street in Denizli province Pamukkale district Karahayıt neighbourhood (Fig. 2). The images were collected together with the LiDAR measurement in 2 road potholes. In this way, both SfM and LiDAR evaluations could be made.

Infrastructure work is estimated to be the main cause of three of the road potholes. The other pothole is estimated to have emerged after the asphalt lost its properties and was neglected.

Figure 2. Study area location of Denizli province

These road surface stresses, which are thought to have occurred after the infrastructure work in the study area, can be detected by both LiDAR sensor and image processing methods (Fig. 3). Here, it is important that the repair work suitable for the road surface is prioritised in the maintenance processes to be made later. This has a significant impact on road comfort. The data obtained for this purpose is used as important information in applications such as asphalt volume calculation, depth detection and asphalt levelling.

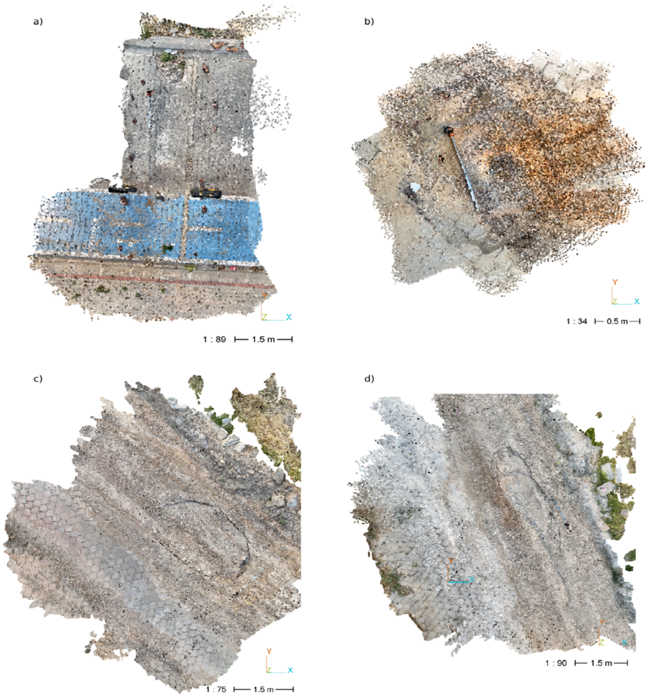

Figure 3. Point clouds obtained with the iPhone 12 pro LiDAR sensor

After Fig.3c and d were brought to the same coordinate system with the best fitting transformation of LiDAR and SfM point clouds, respectively, point-to-point comparison was made and the result in Fig. 4. was obtained. According to these results, it was observed that LiDAR data were not as detailed as SfM. The main reasons for this are that the images have a better resolution than the LiDAR sensor, the iPhone inertial measurement unit (IMU) sensor measurement precision is low, the image matching algorithms determine with high accuracy and detect homologues points on the images.

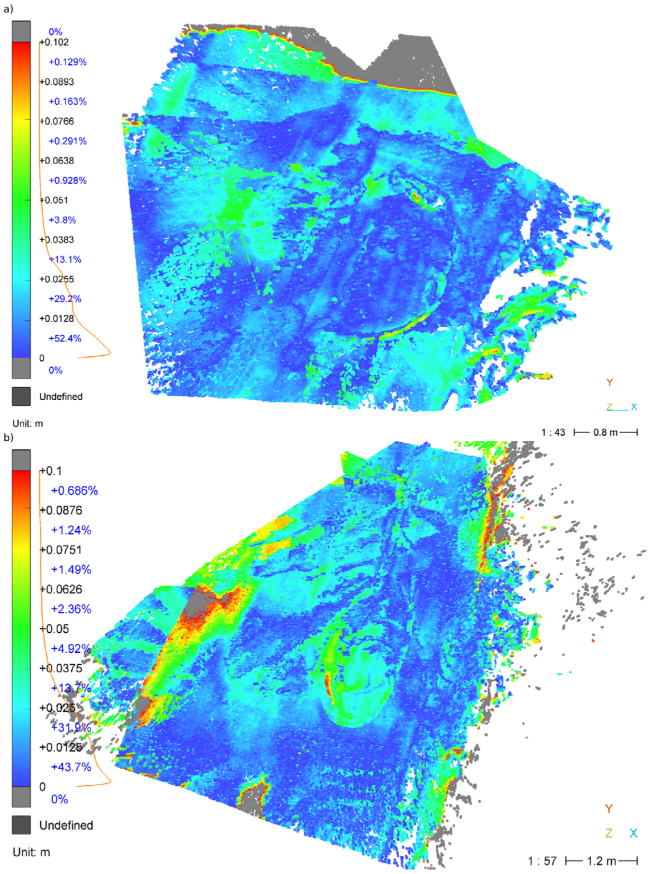

Figure 4. iPhone 12 pro LiDAR sensor vs. SfM point clouds cloud-cloud

3. RESULTS

Within the scope of the approach proposed in the methods section, two different data were obtained. They are point clouds with LiDAR sensors and based on SfM. The region growing algorithm applied to these point clouds was established on the plane in the area determined after the growth and the depths of the potholes were attained.

According to the results obtained, the region growing algorithm has eliminated an important problem. This is the problem of where to get the suitable fitting plane points and region. Although there is manual determination at this stage, the plane can be determined even by selecting at least 1 seeding point from the regions close to the plane and close to the pothole edge. However, it is visible that choosing at least 4 points is more beneficial. It is clear that the LSE estimation is sufficient for plane formation. Determining the differences from the plane as positive or negative according to the surface normals also allowed the investigation of the pits' maximum depths and whether there are points higher than the leveling in the surrounding areas.

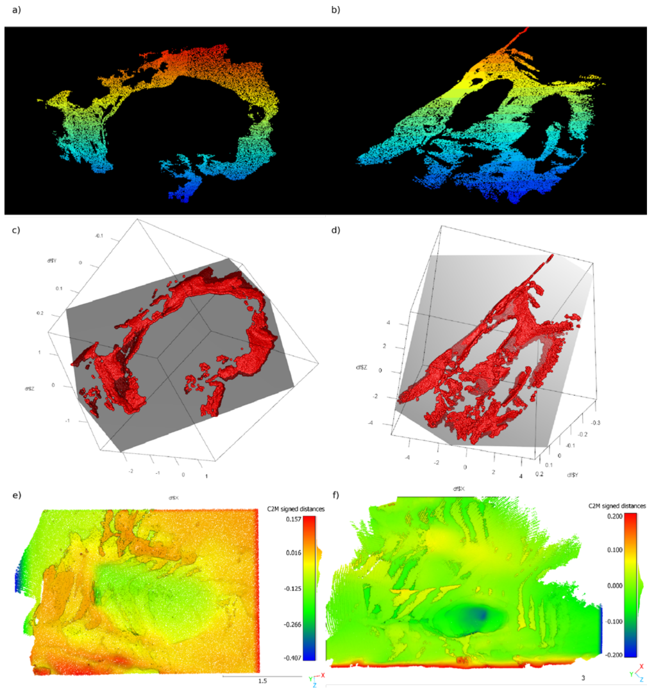

Figure 5. Analysis of the depressions that emerged after the roadwork, two different data sets are shown a,b) The surface points determined by the Region growing algorithm, these points were determined with a tolerance of 1 cm. c,d) fitting the LSE based plane of planar points, e,f) distance of all point clouds to the plane (deviation)

An important result obtained is the presence of alignment errors in the LiDAR data, which emerged both in the comparison of SfM point clouds with LiDAR point clouds and in the analysis of deviations from the plane. In this case, it has been revealed that these points are points that have the error of combining with the overlapped measurements. These points should be deleted or ignored.

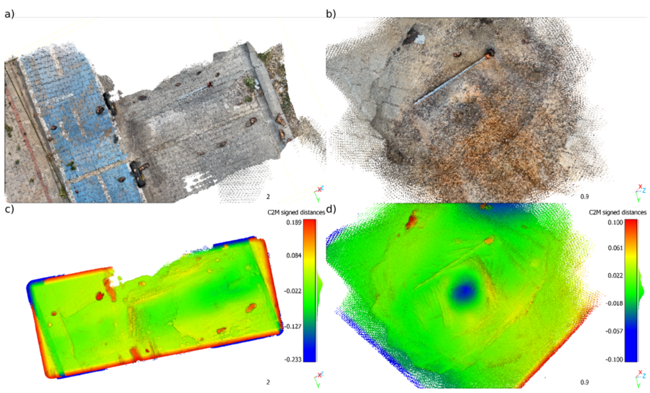

Figure 6. The analysis of the depressions after the roadwork and as a result of neglect, two different data sets are shown a,b) Although there is RGB information when the point clouds are viewed from above, one can see that the depressions cannot be determined but c,d) appear after the plane deviations.

According to Fig.5e, the presence of potholes deviating from the plane around 12 cm and 10 cm could be detected. In addition, alignment errors, which are thought to be caused by the IMU, have occurred at a high rate.

According to Fig.5f, serious depressions reaching a maximum depth of 15 cm were detected. In addition to these depressions, noisy points were also encountered in this data set.

According to Fig. 6, depressions at a level that could be difficult to see with the naked eye could be detected on the road surface at the field stage. These deviations were determined to be in the range of 3 to 8 cm.

4. DISCUSSION

In recent years, laser scanning devices integrated into mobile phones and tablets have been used as a data collection tool. In this regard, Aslanlı Fountain research has been carried out recently using the same LiDAR sensor but a top model cell phone iPhone 13 pro lidar sensor (Aslan & Polat, 2022). According to the results of the study, although it is mentioned that the iPhone 13 lidar sensor can be used to collect data about short-term outdoor objects and it is possible to rescan to increase the data density, it is seen that IMU errors occur. For this reason, if the object dimensions are over 5x5 m, data with iPhone LiDAR should be taken piece by piece and merged, not in an overlay point cloud. In the same study, it was mentioned that it can be used when integrated with photogrammetric data. In this study, it was revealed that the sensitivity of photogrammetric data was better. However, iPhone LiDAR is seen as useful in small-scale studies where instant viewing and fast results are required. Combining it with photogrammetric data will make point clouds noisier. In addition, it seems that this will not be needed from the perspective of many disciplines. LiDAR data generates RGB information.

Another study was done by Kuçak, Erol, and Alkan (2023). During the scanning of objects with too much detail compared to Kuçak et al. (2023), better quality point clouds could only be obtained if measurements were made from a distance of approximately 1 meter with the appropriate scanning options of the software used. Since Kuçak et al. (2023) only made distance comparisons in his study, he did not mention the absolute positional change due to angular accuracy. In fact, making angular examinations besides the distance creates IMU-induced errors in repeated measurements in overlapping areas. The main reason for this is that the measurement fineness of the IMU sensor in iPhone and iPad devices is a rough sensor and designed for virtual reality applications, not for geomatic engineering purposes.

According to the studies examined, mobile cell phone LiDAR sensors, which are promising in distance and 3D modelling studies, can also be used in engineering and road works, but the current user requires experience before measurement and engineering knowledge to be able to analyse after measurement. It should be noted that iPhone sensors are not produced to collect data with very high accuracy and density. Measurements made in this context should be done meticulously, data transformations and analyses should be evaluated in accordance with statistical information such as Kuçak et al. (2023). The ignored limit and tolerance of the errors that occur are also dependent on the user's knowledge. Since the applications used in this study were obtained from open access and free versions, the units working with memberships were not evaluated. In the future, it is expected that better results can be achieved by developing SLAM-based applications which export trajectory information besides IMU, post-processing with GPS time, loop closure and SLAM based on trajectory information.

5. CONCLUSION

This study investigated the inquiry of depressions on road surfaces using the iPhone LiDAR sensor. In four different datasets, the detection and analysis of road potholes were completed with the LiDAR point cloud region growing algorithm-based and plane-fitting process. At the same time, 3D analysis and LiDAR point clouds were compared with the help of images using SfM-based software in the data set. After comparison, it has been determined that SfM-based point clouds produce more sensitive data. In the point clouds obtained from LiDAR sensors, offsets were detected in the overlapped misalignment measurements. However, when these misalignments were excluded from the evaluation, it was possible to carry out and interpret the relevant study. As a result, it has been seen that LiDAR sensors in mobile phones have the potential to be used in small engineering projects. It is foreseen that these problems can be reduced in the near future with improvements in sensor technical features and algorithms. Therefore, it is clear that instant solutions of road surfaces can be possible in bringing instant and fast solution suggestions.

Author contributions

MZ contributed to the writing of the article with the idea of the article, field study and analysis. DE contributed to the fieldwork and article writing.

Conflicts of interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

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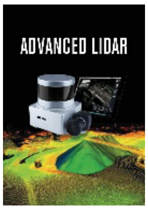

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Creating Architectural Surveys of Traditional Buildings with the Help of Terrestrial Laser Scanning Method (TLS) and Orthophotos: Historical Diyarbakır Sur Mansion

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ABSTRACT

Manual mapping or traditional methods of architectural documentation by an expert in historical buildings are today considered time-consuming and laborious procedures. In recent years, with the development of technology, the use of digital tools to support architectural documentation activities has provided more detailed results on architectural analysis and has simplified processes which were performed manually. The Historical Sur Mansion, located in the Diyarbakır urban protected area, which is the subject of the study, is a historical building that reflects the general characteristics of traditional houses in Diyarbakır, containing its own characteristics, formed by factors such as topography, materials, climate as well as cultural elements in the immediate environment. The building has been registered as a "monumental" structure to be protected by the Council of Europe's Natural and Cultural Heritage Conservation Inventory and the General Directorate of Turkish Cultural Heritage and Museums. The decorations and inscriptions on the iwans, window and door openings of the building are examples of Diyarbakır residential architecture. The aim of the study is to obtain the analytical surveys of the historical Sur Mansion, which is a great necessity for the sustainability of the cultural heritage in the region, by using orthophotos produced by various techniques from laser scanning as a base. Researches carried out on the studied area have shown that by using the orthophotos produced from the data obtained from terrestrial laser scanning as a base, data with sufficient level of detail needed in architectural documentation can be obtained today, and this method offers an economically effective and fast solution to produce analytical surveys.

1. INTRODUCTION

Manual mapping of architectural documentation in historical buildings or detection by an expert using traditional methods are today considered time-consuming and laborious procedures (Barber et al., 2006). In recent years, with the development of technology, the use of digital tools to support architectural documentation activities has provided more detailed results on architectural analysis, thus simplifying processes which were performed manually (Del Pozo et al., 2016). In recent years, among the technologies used in architectural documentation, terrestrial laser scanning, photogrammetry and unmanned aerial vehicles called "drone" are frequently seen. In particular, surveys based on terrestrial laser scanning (TLS) tools enable to obtain very good geometric data in terms of high resolution, high accuracy and low uncertainty, and to obtain dense point clouds that are useful in architectural documentation (Comert et al., 2012; Russo, 2017).

It is emphasized that the use of laser scanning method instead of traditional methods greatly reduces the time and effort required in field studies and drawing processes, as common in the studies carried out to verify the usability of the terrestrial laser scanning method, which has proven to be a promising technique, especially in the last decade (Alptekin et al.,2019; Alyilmaz et al.,

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2010; Guldur et al.,2015; Karataş et al.,2022; Korumaza et al., 2010; Korumaz et al.,2012; Lerones et al., 2010; Ulvi et al., 2016; Şasi & Yakar, 2017; Ulvi & Yakar, 2010; Ulvi & Yakar,2014; Yakar et al.,2009; ; Yakar et al., 2015; Yakar & Mirdan, 2017; Yakar & Doğan, 2019; Yakar & Omar ,2016; Yakar, 2015; Yılmaz & Yakar, 2006; Olsen et al.,2010; Doğan & Yakar, 2018 ; Yakar et al.,2010; Yakar et al.,2014; Yakar& Doğan, 2017).

Many studies in the literature show that terrestrial laser scanning method provides great convenience in architectural documentation when used in integration with photogrammetry method (Mohammed at all., 2016; Ulvi at all., 2014; Uysal at all., 2013; Kocaman & Yakar, 2017; Kanun at all., 2017) (Kaya, Y. at all 2021) (Yılmaz,.& Yakar, M. 2000) (Mirdan, O., at all. (2017)(Yilmaz, I at all 2004) (Pulat, F at all 2022). Especially for the documentation of stone structures in the field of cultural heritage, there are various studies that have concluded that by creating orthophotos with various software on the structures obtained by using terrestrial laser scanning, they can obtain the data that will be the base for the facade, plan and section drawings required for the relief plans (Comert et al.,2012; Gabriele et al.,2010; Georgopoulos et al.,2004; Koska & Křemen, 2013; Meroño et al.,2015; Mol et al., 2020; Stober et al., 2018; Yılmaz & Yakar, 2006). Koska & Křemen (2013) used a combination of terrestrial laser scanning and photogrammetry and confirmed that the resulting scaled orthophotos can be used to create building plans, 2D drawing documents of facades St. Nicholas Baroque Church. Gabriele et al. (2010) performed the internal and external scanning of the Italian Carignano Vallinotto temple and created the 3D model and orthophoto images of this temple, and obtained the data that will be the base for the orthophoto images and the relief plans for the facade, plan and section drawings. Comert et al. (2012)(Ulvi, A. At all 2019) scanned the former military office building in the Seyitgazi district of Eskişehir with the terrestrial laser scanning method and obtained a 3D model, and stated that orthophoto images, drawings of the facades and plans produced from this model could be produced. He stated that orthophoto images bring great convenience to architectural facade drawings, and orthophoto images obtained from point cloud allow architectural plans and facades to be drawn with millimeter precision since they contain many details. Georgopoulos et al. (2004) shows in a case study of a 15th century Byzantine church that orthophotos produced from laser scanning can be used as a base for architectural documentation, even in precision drawings. He explains that in this way it is possible to eliminate the necessary control data to be obtained using standard measurement techniques, thus reducing the time of field and office work.

As stated in the literature, with the development of technology in recent years, the use of terrestrial laser scanning and orthophotos to support architectural documentation activities has provided more detailed results on architectural analyzes, thus simplifying manual operations. The Historical Sur Mansion, located in the Diyarbakır urban protected area, which is the subject of the study, is a historical building that reflects the general characteristics of traditional houses in Diyarbakır, containing its own characteristics, formed by factors such as topography, materials, climate as well as cultural elements in the immediate environment. The building has been registered as a "monumental" structure to be protected by the Council of Europe's Natural and Cultural Heritage Conservation Inventory and the General Directorate of Turkish Cultural Heritage and Museums. Sur Mansion, which is located in the urban protected area in Diyarbakır, has been in existence for years despite being exposed to many environmental effects. The building, which was built of basalt and limestone, was able to preserve its originality to a large extent. The decorations and inscriptions on the iwans, window and door openings of the building are examples of Diyarbakır residential architecture. The aim of the study is to obtain the analytical surveys of the historical Sur Mansion, which is a great necessity for the sustainability of the cultural heritage in the region, by using orthophotos produced by various techniques from laser scanning as a base.

In line with the determined purpose, within the scope of the article, first of all, a source research on the structure and an observational analysis on the structure were made. In the next stage, the systematic of the stages to be followed in order to create the analytical surveys of the building is presented, and the findings about the floor plans and facades are obtained. In the discussion section, the results of the study are discussed and in the conclusion section, conservation suggestions are made to ensure the sustainability of the building.

2. STUDY AREA

The building is located in Diyarbakır Province Sur County, Savaş District, Ali Emiri Street No: 9-11. According to the land registry records; Located on Block 382, parcel no. 47 (Figure 1).

The building has been registered as a "monumental" structure to be protected by the Council of Europe's Natural and Cultural Heritage Conservation Inventory and the General Directorate of Turkish Cultural Heritage and Museums (Figure 2). There is no information about the construction date of the building in the sources. The inscriptions in the building do not contain information about the history of the building. On the inscriptions on the eastern wall of iwan 1 and the western wall of iwan 3, "El Baki El Hallak" is written in Arabic thuluth calligraphy. Considering the plan of the house, the materials used, the construction form and the construction date of similar example houses, it is estimated that the building was built in the XIX or XX century. It is known that the house numbered 382 47 was used as a school for the deaf in the 1950s. In our research, the building served as a school for 10 years and then moved to its new location. Only written and oral sources could be reached, and no visual data could be found about the period when the building was used as a school. The oldest document belonging to the building is the measurement sketch dated 1952 taken from the archive of the cadastral directorate. There is also the Savings sketch of the building drawn in 1953. It is stated that the building shown in plot no. 27 on the savings sketch is a masonry house and it is owned by Marton Pedros Velesi

Şemu Ef Foundation. Another document is the aerial photograph published by the Diyarbakir Promotion, Culture and Solidarity Foundation in 1966. In addition, photographs taken from the Diyarbakır Cultural Inventory show the state of the building before it was destroyed (Figure 3).

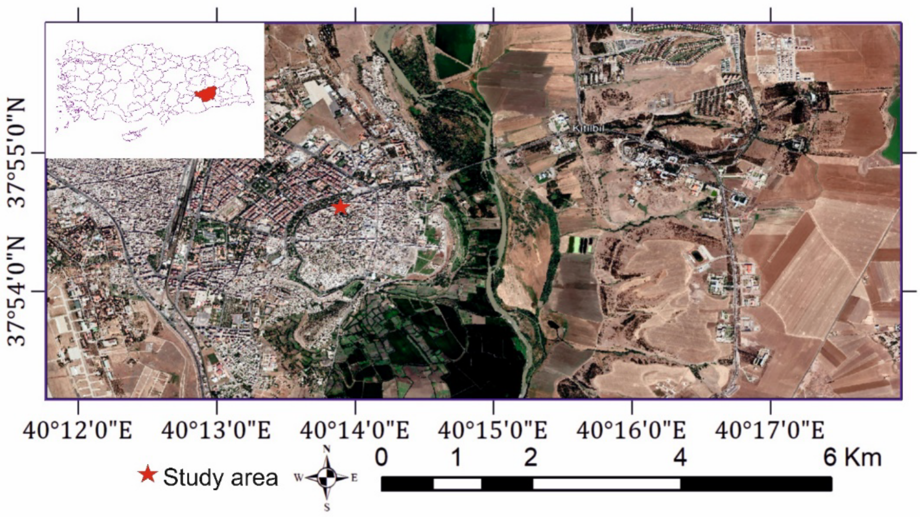

Figure 1. Location map of the study area

Figure 2. Current state of the building

Figure 3. The original state of the building

3. Method

Literature research and terrestrial laser scanning methods were used to create the architectural analytical surveys of the structure determined in the study. In the first stage of the research, general information on the historical structure where the case study will be applied was presented within the scope of an archive review and the data obtained from the Diyarbakır Metropolitan Municipality Kudeb archive.

3.1. Situation Analysis

In order to understand the relationship of the building with its environment, it is necessary to conduct research on the structure, its general structure, form, material and environment (Karkaş & Özgünler, 2021). In this context, in this first stage, all information about the historical documents about the building, its changes over time, spatial and facade features, material and construction technique and material deterioration in the current situation were collected. In the next stage of the study, a laser scanning device (Faro Focus Laser Scanner) was used in the building to obtain architectural drawings of the building and point clouds were obtained during scanning. The steps followed for the preparation of the analytical surveys of the architectural features of the building are explained systematically in this section.

3.2. The Obtaining the Point Cloud

In the next stage of the study, a laser scanning device (Faro Focus Laser Scanner) was used on some of the building facades to obtain images of the building facades and point clouds were obtained during scanning. Objects up to 330 meters can be scanned with the device used (Figure 4).

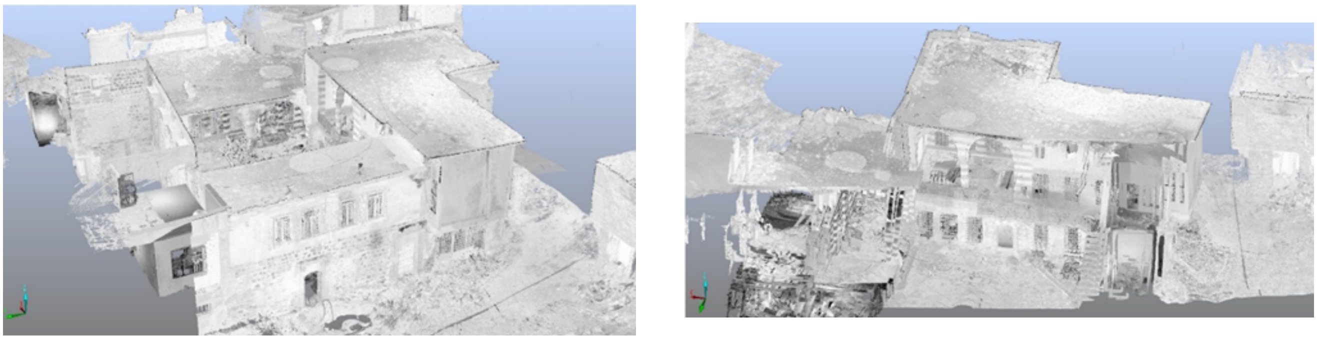

Figure 4. Obtained point cloud of the structure

3.3. Obtaining Orthophotos

At this stage, 3D images of the structure were obtained by using the point clouds obtained in the laser scanning process using the software called PointCab Origins 4.0. Using the software called PointCab Origins 4.0, sections were taken from the desired places on the 3D images of the building and scaled orthophotos of the plan and facades of the building were produced (Figure 5-8).

AutoCAD program was used in the process of creating the drawings of the facades. Before starting the drawing process, orthophoto images produced in PointCab Origins 4.0 software were transferred to the AutoCAD environment. It can be transferred to AutoCAD environment in TIF file format with .tif or .tiff extension, which is the common data format of AutoCAD software. Using the scaled orthophoto images obtained, the facade drawings of the building were obtained with the Autocad program.

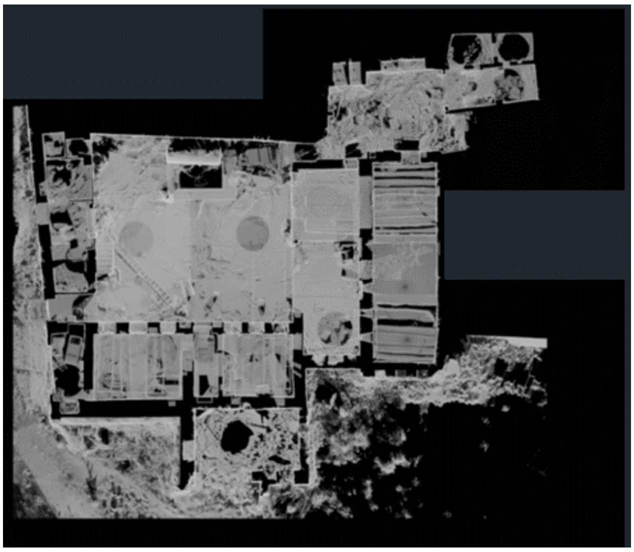

Figure 6. Orthophoto of the ground floor plan

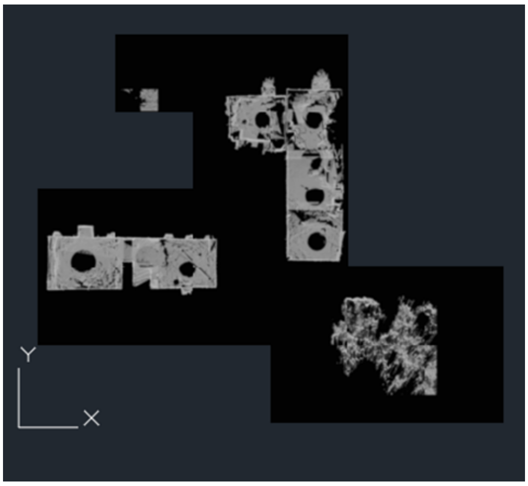

Figure 5. Orthophoto of the basement floor plan

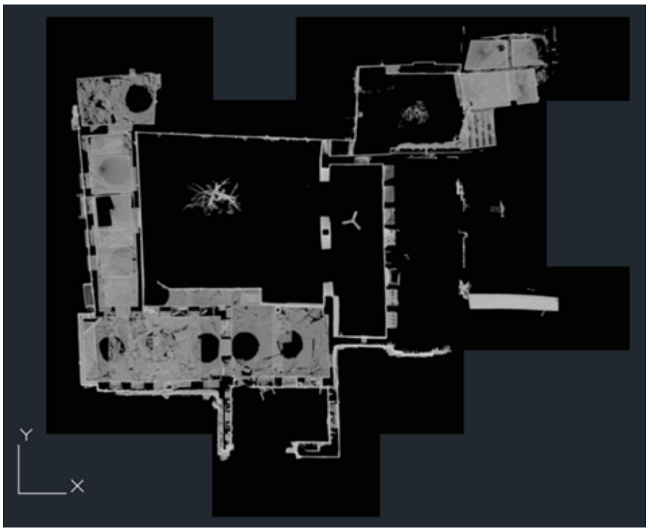

Figure 7. Orthophoto of the first floor plan

Figure 8. Orthophoto of the western façade

Figure 8. Orthophoto of the south façade

4. RESULTS

After evaluating the macro and micro visual observations made in the previous section, the current situation analysis of the building or monument and the analytical drawings obtained from the orthophotos obtained from laser scanning, the following findings have been reached.

4.1. Floor Plan Surveys

In the house, which was built in a "U" plan around the square planned courtyard, smooth cut basalt stone and limestone were used. Basalt stone is the main building block of historical artifacts in and around Diyarbakir province. The structure, consisting of east, west and south wings, was built of basalt stone. Basalt stone was used mainly on the courtyard facades. The spaces forming the south wing were built of basalt stone, and limestone stone and wooden beams were used. The same is true for the spaces that make up the east and west wings, but the rooms on the upper floor of the west wing are made of today's building materials. All rooms have basalt stone floors and wooden beams (Figure 9).

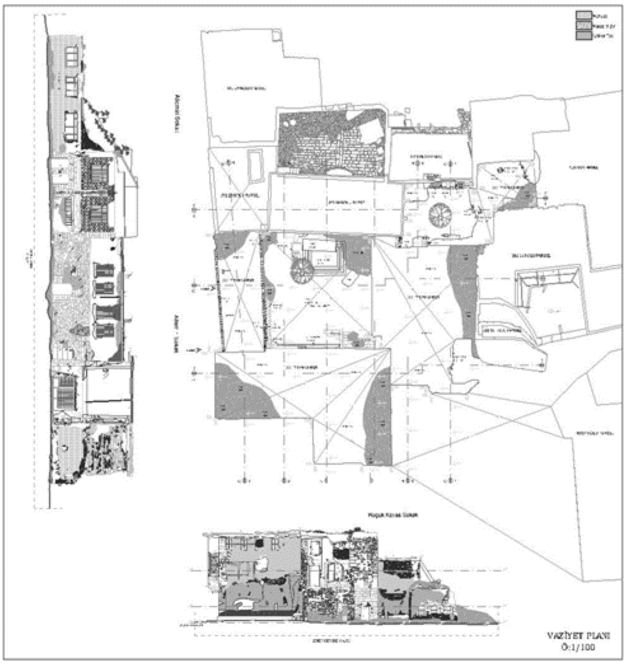

Figure 9. Building site plan survey

The building consists of south, east and west wings. East wing consists of basement and ground floor, south wing consists of basement, ground and first floor, and west wing consists of ground floor. The second courtyard is accessed from the northeast of the courtyard. On the north of this courtyard, there are two toilets, two rooms, and a woodshed in the east. The spaces in the west wing of the building are the courtyard and the WC. There are 6 rooms, 1 shop, iwan and kitchen in the south wing of the building. The spaces on the eastern wing of the building consist of 4 rooms and an iwan (Figure 10-12).

The walls of the building have been destroyed due to material loss in the rooms. In addition, deteriorations such as plaster-paint spills, cracks and surface contamination were observed on the plastered wall surfaces.

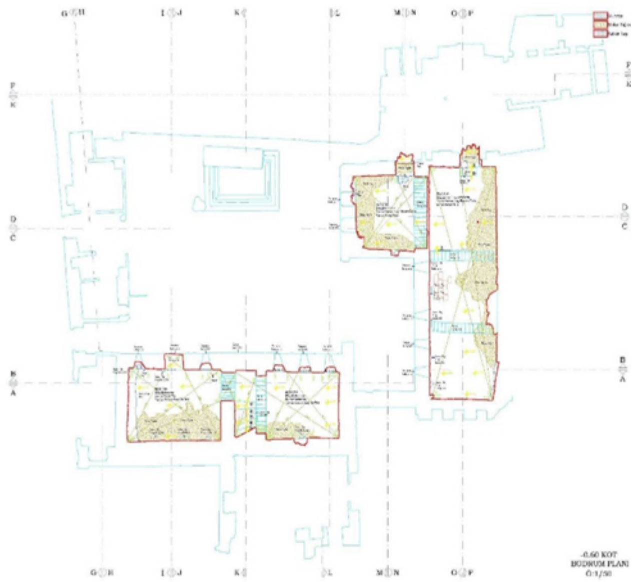

Figure 10. The basement floor survey of the building

Figure 11. The ground floor survey of the building

Figure 12. First floor survey of the building

4.2. Facade Surveys

The south façade wall consists of adobe, rubble stone, blend brick, basalt stone and plastered wall surfaces. The south façade wall consists of the south wing of the building and the south wall of the west wing. The façade wall is more clearly observed by the demolition of the building on the neighboring parcel. Intense deterioration is observed on the facade wall. Intense plaster-paint spills, especially destructions and material loss on the wall surface, and surface contamination on stone surfaces were observed. The upper level of the façade is formed by a reinforced concrete flat roof (Figure 13).

The west façade wall consists of rubble stone, basalt stone and plastered wall surfaces. The facade wall consists of door and window openings and a bay window. The façade wall was built with rubble stone up to +3.62 elevation. There are two entrance doors in the area covered with rubble stone. The entrance gates built with basalt stone have a basalt stone arch measuring 1.85x0.98 m. There is also a basalt eaves resting on two basalt stone pendentives. The wooden heeled door in one of these door openings opening to the courtyard entrance hall has managed to preserve its originality. Four rectangular PVC window openings on the upper elevation of the wall have metal railings. A 2.80x2.12 m opening belonging to the shop is seen on the east of the façade wall. Above this area is a bay window. The door openings, basalt stone pendentive, eaves and wooden heeled door on the façade wall have managed to preserve their originality. Interventions were made with cement-added mortar on the stone wall surfaces of the façade. However, it has been determined that structural deteriorations, especially surface pollution, occur on stone surfaces. The upper level of the façade is formed by a reinforced concrete flat roof (Figure 14).

Figure 13. Analytical survey of the south façade of the building

Figure 14. Analytical survey of the western façade of the building

The south façade of the building in the courtyard consists of three floors. There is a door opening on the middle axis of the ground floor main wall that provides the entrance to the building. In the eastern part of the entrance door, there are three rectangular-planned three window spaces with iron bars in front, two rectangular-planned window spaces with iron railings in front, and a staircase that provides access to the upper floors of the building. On the first floor of the building, there are two iwans with a height of 6 meters on the right side of the central axis of the main wall, and three window spaces in two rows, with a rectangular plan in front of them, on the left side. There is a section supported by buttresses on the part connecting the ground floor and the first floor on the façade (Figure 15).

The west façade facing the courtyard consists of two floors, and two closed iwans are visible on the ground floor (Figure 16).

The east façade, facing the courtyard, consists of two floors, and two iwans with pointed arches forming large openings can be seen on the façade (Figure 17).

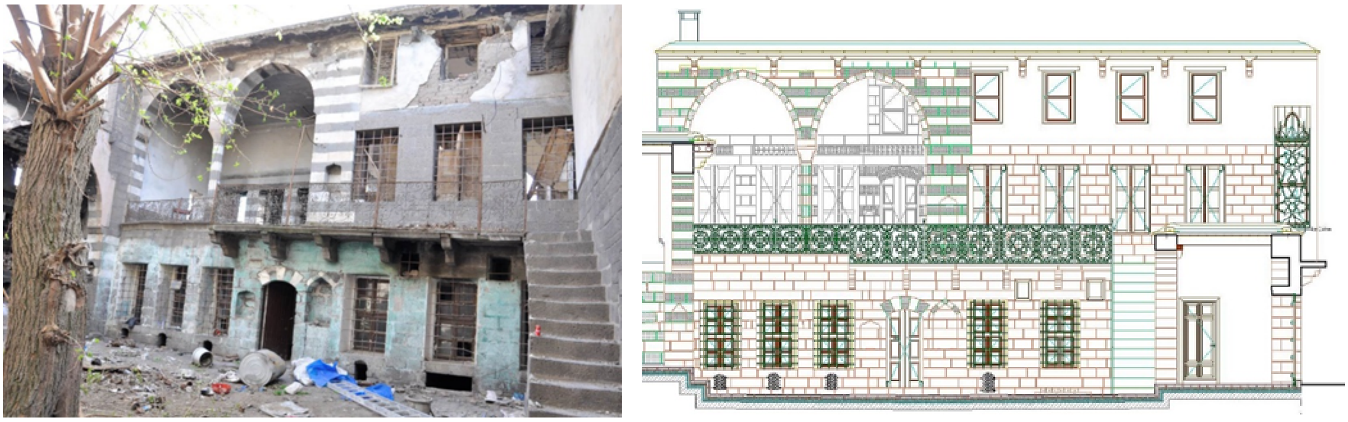

Figure 15. Analytical survey of the south façade of the building facing the courtyard

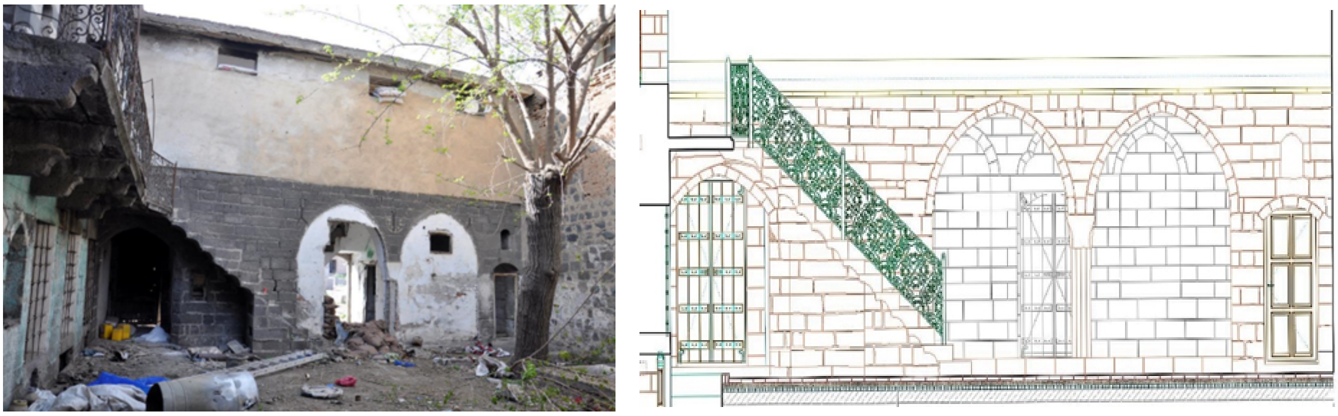

Figure 16. Analytical survey of the western façade of the building facing the courtyard

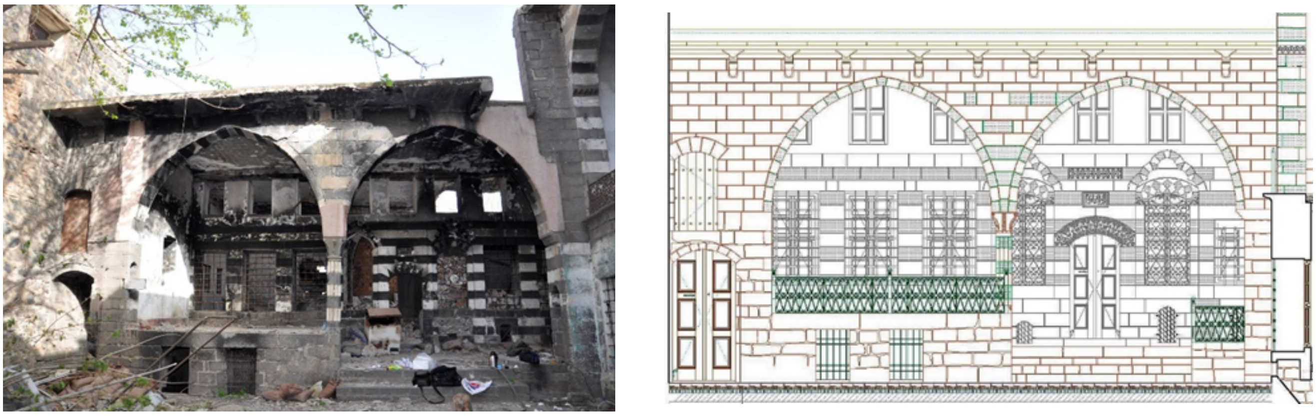

Figure 17. Analytical survey of the east façade of the building facing the courtyard

5. DISCUSSION

The study aims to document the architectural features of the historical Sur Mansion, which is a great necessity for the sustainability of the cultural heritage, by obtaining analytical surveys. In the study, architectural analytical relief drawings of the historical building were created by using orthophotos produced by various techniques from laser scanning as a base. Research carried out on the studied area has shown that by using orthophotos produced from data obtained from terrestrial laser scanning as a base, it can offer an effective and fast solution to produce analytical surveys in an economical and with sufficient level of detail needed in architectural documentation today. This result supports the fact that the use of laser scanning method instead of traditional methods in documentation studies, which is emphasized in many studies to verify the usability of terrestrial laser scanning method in architectural documentation, greatly reduces the time and effort needed in field studies and drawing processes (Alptekin et al. al.,2019; Alyilmaz,2010; Guldur et al.,2015; Karataş et al.,2022;Korzaza et al., 2010; Lerones et al., 2010; Ulvi et al., 2016; Şasi & Yakar, 2017; Ulvi & Yakar, 2010; Yakar et al.,2009; ; Yakar et al., 2015; Yakar & Mirdan, 2017; Yakar & Doğan, 2019; Yakar & Omar ,2016; Yakar, 2015; Yılmaz & Yakar, 2006; Olsen et al.,2010) .

In the study, it is seen that by creating orthophotos with various software on the 3D point clouds of the structures obtained by using terrestrial laser scanning, we can obtain the data that will be the base for the facade, plan and section drawings required for the relief plans. This finding supports the studies that determined that sufficient data can be obtained for architectural documentation by using orthophotos as a base (Comert et al.,2012; Gabriele et al.,2010; Georgopoulos et al.,2004; Koska & Křemen, 2013; Meroño et al. ,2015; Mol et al., 2020; Stober et al., 2018; Yılmaz & Yakar, 2006).

In addition, all the necessary details can be drawn from the data obtained as a result of the study, even for the details on the facades, Comert et al. (2012) and Russo (2017) support the fact that terrestrial laser scanning (TLS) tools do not provide to obtain very good geometric data in terms of high resolution, high accuracy and low uncertainty and to obtain all the details useful in architectural documentation.

6. CONCLUSION

The Historical Sur Mansion, located in the Diyarbakır urban protected area, is a historical building that reflects the general characteristics of traditional houses in Diyarbakır, containing its own characteristics, formed by factors such as topography, materials, climate as well as cultural elements in the immediate environment. The decorations and inscriptions on the iwans, window and door openings of the building are examples of Diyarbakır residential architecture. Research carried out on the studied area has shown that by using orthophotos produced from data obtained from terrestrial laser scanning as a base, it can offer an effective and fast solution to produce analytical surveys in an economical and with sufficient level of detail needed in architectural documentation today.

The architectural documents obtained as a result of the study show that the building has been exposed to material damage to a large extent. Intense deterioration is observed on the facade wall. Intense plaster-paint spills, especially destructions and material loss on the wall surface, and surface contamination on stone surfaces were observed. Interventions were made with cement-added mortar on the stone wall surfaces of the façade. However, it has been determined that structural deteriorations, especially surface pollution, occur on stone surfaces.

In this context, it is necessary to apply various protection interventions to the building in order to ensure the sustainability of the building. Necessary measures should be taken against the deterioration caused by rain water in the house. Since the construction of the top cover with cement-based material in its current state damages the structure, precautions should be taken for the natural conditions that will damage the structure in the first place, and the deformed roof cover should be replaced. The basalt stone roof, which has lost its feature, should be removed and rebuilt in accordance with the original. After the concrete top cover is removed, it is recommended to build a clay soil roof based on the stages specified in accordance with the project.

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Author contributions

Lale Karataş; Methodology, data collection, writing **Aydın Alptekin;** Writing, Control. **Murat Yakar:** Editing the manuscript

Conflicts of interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

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