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Comparative analysis of non-invasive measurement methods for optimizing architectural documentation

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Abstract
Architectural documentation not only plays a critical role in the conservation of historical structures, but also enables their detailed comprehension of the structure. This study aims to assess the most effective methods for drawing and modeling architectural structures and present their advantages and disadvantages. Measurements play a significant role in this context, and today's technology offers the potential to accelerate this process and enhance accuracy. However, the application of these technologies can impose additional burdens such as elevated expenses, the requisite for specialized personnel, and the management of substantial data volumes. Therefore, determining the appropriate measurement method in line with the quality of architectural documentation is essential. For this study, the Mosque of Kurşunlu Complex in Eskişehir was selected for its historical and topographical attributes which enabled all methods to be examined. The data produced via terrestrial laser scanning, aerial photogrammetry and terrestrial photogrammetry methods were examined in terms of the production of drawings and models for different analysis methods such as structure, daylight and building acoustics, as well as survey drawings required for the architectural documentation processes of the building. The study concluded that no single method could produce holistic data on its own, and the best results for comprehensive documentation were achieved by integrating terrestrial laser scanning and aerial photogrammetry. Furthermore, for products that do not require comprehensive data, photogrammetric methods were more efficient.

1. Introduction

Historically, structures have not only provided functional spaces but have also been expressions of humanity's engineering and aesthetic capabilities. The long-term and effective use of these structures requires maintenance, repair, enhancement, and restoration. Consequently, the need for drawings of the structure is essential, serving as guides that enables us to understand and manage the building. However, in some cases, two-dimensional architectural drawings do not suffice. For example, when analyzing building physics such as statics, lighting, sound, ventilation, heating, etc., in a digital environment, three-dimensional models are also required. Also the use of 3D drawings is of great importance for both academic studies and applied conservation studies. They play a crucial role in restoration planning, improving stakeholders' understanding and contributing to the archiving and reconstruction of cultural heritage [1, 2]. The measurement process is crucial in achieving the precision required for the drawing or model production to meet specific needs. Comprehensive architectural documentation, for instance, can prevent the building from performing its original function throughout the documentation process, or, if the building is a cultural heritage, it may not be accessible for visitors during this process. To prevent such situations documentation should be executed with minimal intervention. Therefore, it is essential to keep the process short and minimize contact with the structure to obtain accurate data.

Non-invasive technology methods contribute significantly to architectural measurement in terms of speed and precision [3]. However, these methods can pose disadvantages in some cases due to their high cost, the need for skilled personnel, and large data sizes [4]. Furthermore, in architectural documentation, the location of the building, surrounding structures or objects, architectural features of the building, current functionality, and even ornamental details directly impact the choice of documentation method. Consequently, it is important to determine a method that is suitable for all these conditions before starting an architectural documentation project. This study attempts to determine the most effective non-invasive methods offered by technology for different types of drawings and solid model productions required by various methods of analysis.

2. Method

2.1. Measurement methods

Recent advancements in technology have facilitated the effective utilization of digital measurement methods in the documentation of cultural heritages [5]. These developments have brought significant progress in terms of precision and accuracy, strengthening efforts in the conservation of historical and cultural heritage. These methods, which basically detect three-dimensional depth using light, are divided into active and passive methods throughout literature. Active methods, which generate their own energy, include techniques such as lidar, radar, tomography, and holography. Passive methods that rely on measuring light without an independent energy source include photogrammetry, shape from focus, and microscopy. These methods are diverse in their application depending on the characteristics of the object to be documented [6].

Both active and passive methods are effectively used in the documentation processes of cultural heritage assets, each with its own set of advantages and disadvantages. Therefore, these methods have been integrated to capitalize on their respective strengths. In architectural documentation, the most preferred methods are laser scanning and photogrammetric techniques, which are also evaluated in this study.

Utilized since the early 1980s, terrestrial laser scanning technologies offer the advantage of rapidly generating large volumes of data. However, they have a limited capacity to produce precise data from the upper surfaces of tall structures and sharp corners, as well as limitations in documenting the visible light range. Consequently, additional photogrammetric measurements may be required for color data acquisition [7].

Photogrammetric methods offer solutions that are much more affordable. They can provide better results in terms of documentation of texture and colors, but require expertise in the stages of data production and processing [8]. Besides, the data production density and sensitivity are lower than laser scanning [7].

2.2. Study area

To compare the measurement methods, the Mosque of Kurşunlu Complex, a 16th century structure located in the historic district of Odunpazarı in Eskişehir, Turkiye, was selected. This structure was chosen because it presents different levels of challenges for measurements to be carried out with the aforementioned methods. The building is still in use as a mosque, and it is located in a historical area, therefore having a constant flow of visitors. This directly affects the day and time range of the measurements. The mosque is also located within a courtyard of a complex with trees of different heights and buildings with different functions. These elements were also effective in the selection of the tools to be used for the measurement. The topography of the building, its architectural details, its single entrance and ornamental details were all factors in determining the suitable measurement method. With this ensemble of distinctive features, the Kurşunlu Complex Mosque was ideal for testing different measurement methods (Figure 1).

The application of non-invasive measurement methods such as optical measurement, aerial photogrammetry, and terrestrial photogrammetry were used to investigate the most effective method for producing drawings and models of the building that are required as input by different analysis methods. The work plan for this process and the software used are presented in Figure 2.

Figure 1. Aerial view of the Kurşunlu Complex [9].

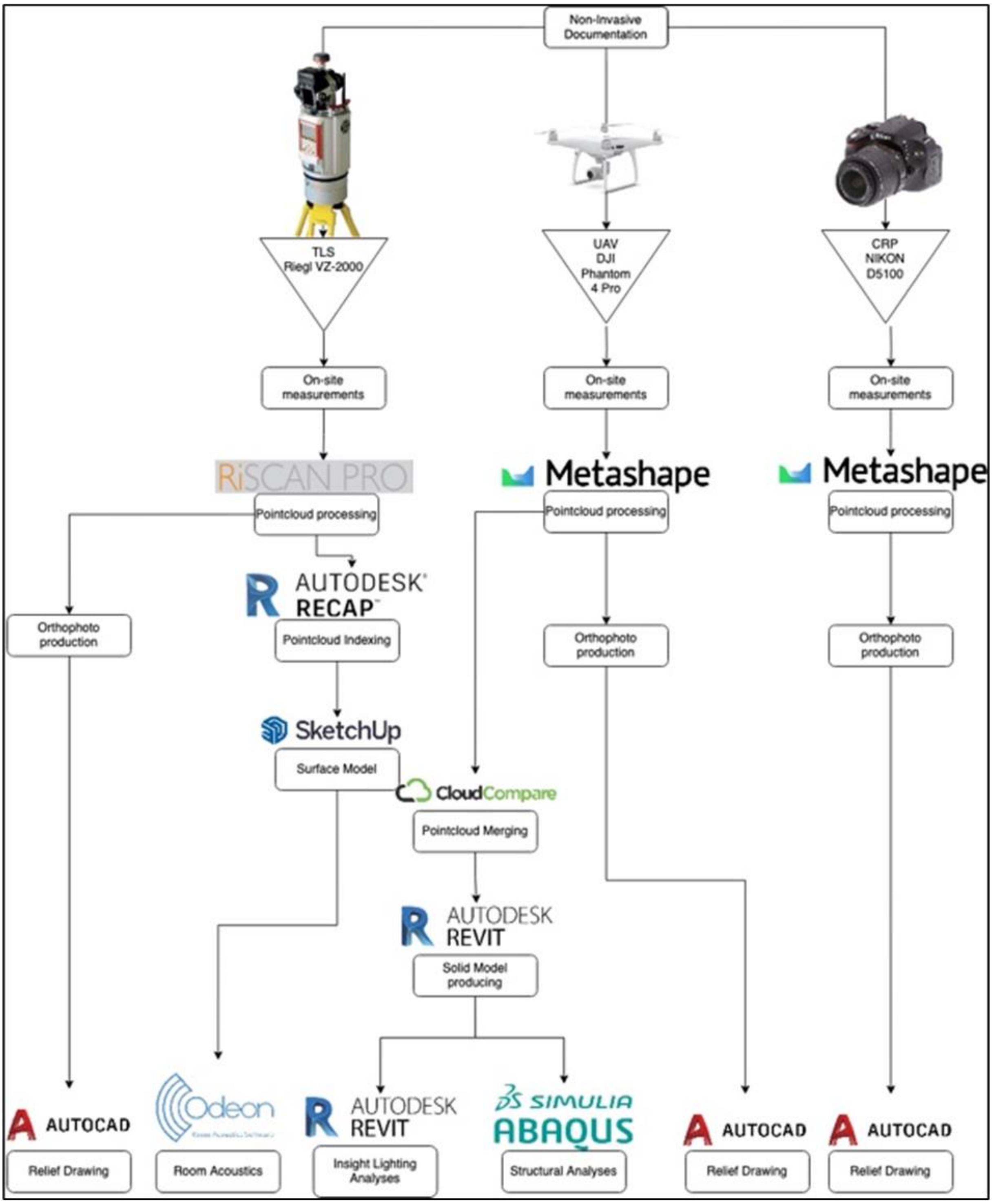

Figure 2. Software used in the study and the workflow.

3. Data collection

3.1. Terrestrial laser scanner

Terrestrial laser scanners can process a large amount of data in a very short time. Modern versions are easily portable and operate without a separate computer, thanks to integrated operating systems [10]. However, these scanners are expensive and require trained personnel to operate [11].

The scanning of Kurşunlu Mosque was conducted using a Riegl VZ-2000 model 3D terrestrial laser scanner. This laser scanner operates based on the principle of time-of-flight. Under the normal light and reflection conditions, it exhibits a sensitivity of 5 mm at 50 meters and can measure within the range of 1 to 2000 meters. The emitted laser beam from the scanner falls within the near-infrared spectrum, with a wavelength ranging from 0.7 µm to 1.3 µm. The scanner has the capability to rotate along a 100° vertical axis and a 360° horizontal axis. The angular resolution of the device can be increased up to 0.001°, and it has the capacity to acquire 400,000 point data per second [12]. The exterior facades and interior volume of the structure were scanned from a total of 20 stations, each with a 0.040° angular resolution. The Kurşunlu Complex site's dense tree coverage and surrounding buildings effect the positioning of the scanning stations around the mosque. For the exterior facades, scanning was conducted from 11 different stations. However, as there was no platform which provided a comprehensive view of the dome surface, sufficient data from the superstructure could not be captured. To produce comprehensive data, it is essential to integrate measurements from both the interior and exterior of the structure. The laser scanner's software, Riscan Pro, allows for the integration of point clouds without the use of reflectors. To achieve this, a sufficient amount of common identifiable surfaces between positions is required. The presence of only one door in the mosque inhibits the positioning of a sufficient common surface between the last externally scanned position and the first internally scanned position. To address this issue, 10 reflectors with a 5 cm diameter were strategically placed in the last external and first internal positions to connect the two groups of point clouds. As for the interior volume of the structure, scanning was conducted from 6 different stations, resulting in 9 scans in total. The aspect ratio of the structure and the height of the dome prevent the entire dome from being captured from a single perspective. Therefore, to gather data of the upper structure, three stations were set up with a vertical angle of 45°. The entire measurement process was completed in 45 minutes, and an average of 7.5 million points were collected from each position, resulting in a total of 222,448,595 points measured.

3.2. Photogrammetric documentation

The photogrammetry method is the process of taking photographs with standard cameras and subjecting them to various corrections to transform them into map-like, measurable images. Photogrammetry is classified based on the location where the image is taken, evaluation methods, or application area. In these methods, essentially, high overlap sequential photographs are taken, allowing for the generation of 3D models and orthophotos. The calibration values of the cameras are of great importance, as well as ensuring that the consecutive photographs taken have at least a 60% overlap ratio [13]. In this study, Kurşunlu Mosque was measured using both aerial photogrammetry and terrestrial photogrammetric methods.

3.2.1. Aerial photogrammetry

Unmanned aerial vehicles (UAVs) are able to perform both pre-planned automated flights and user-controlled flights. Pre-planning variables such as flight altitude, flight path, image overlap ratio, and the number of captured photographs, facilitate faster and more precise acquisition of data. However, conducting automated flights, especially within dense urban environments, is not always feasible due to varying heights and surrounding structures. Manual flight control also requires skilled personnel. UAVs enable the rapid imaging of extensive areas and are more cost-effective compared to terrestrial laser scanners [14].

The planning for the documentation process using the UAV began with the DJI Phantom Professional 3 model. It can be controlled remotely or programmed for various flight modes [15]. As Kurşunlu Complex is a densely populated area and one of the most visited regions in Eskişehir, flight time and day were meticulously determined to minimize any potential hazards. The flight took place around 09:15, after ensuring that a group of visiting students had left the area. To prevent pilot-related errors, the automated flight followed a predetermined route. The circular flight mode, which captures photographs with the object of interest at the center, was selected. To avoid accidents, the flight altitude of the vehicle was set at 35 meters; 3 meters above the minaret, which is the tallest structure in the complex.

The flight plan was uploaded to the UAV, and the flight was initiated. However, due to an oversight in planning the starting point location, the UAV crashed into the minaret between the "home point" and the "starting point", causing damage to the UAV, with its debris scattering across the complex. Thanks to the accurate determination of the flight day and time, no living beings were harmed. Nevertheless, the documentation could not be carried out.

A second flight was conducted using the DJI Phantom 4 Professional model UAV [16]. As in the first attempt, the most suitable day and time for the complex were chosen for the flight. The flight for the exterior of the mosque was completed at 10:08 AM. However, it was not possible to collect data from the interior of the structure using the UAV. Although the UAV was able to enter the building through its single door, its movement was obstructed by the chandelier, preventing comprehensive photographing. Additionally, the camera mounted underneath the UAV can only move vertically up to 45 degrees; rendering it impossible to gather data from the interior's upper structure.

3.2.2. Terrestrial photogrammetry

The number of equipment available for terrestrial photogrammetry studies is increasing. Photogrammetry software can produce map-like, measurable data not only from SLR cameras but also from mobile phone cameras [17]. To obtain these data, it is important not only to be able to identify the calibration values of the equipment used but also to capture photographs with the correct overlap ratio. Therefore, this measurement method can be described as the most cost-effective.

In the study, a Nikon D5100 camera was used with a Nikkor 18-300 mm lens. With a camera resolution of 16MP, 80 high-overlap images were obtained from inside the structure and 140 images from outside.

4. Data modelling

Data collected from the field was processed using different software programs based on the method used. Data generated with the terrestrial laser scanner were georeferenced, merged, and processed into a comprehensive point cloud using its proprietary software, "Riscan Pro". The aerial and ground-based photographs were photogrammetrically processed using "Agisoft Metashape" software.

4.1. Terrestrial laser scanner

Point clouds generated with the terrestrial laser scanner were processed individually for each position. The point clouds were colorized using undistorted images captured by the scanner's camera, and objects around the mosque, as well as reflection noises, were all removed. When the interior and exterior scanning positions were connected, a comprehensive point cloud consisting of a total of 116,821,366 points was generated (Figure 3).

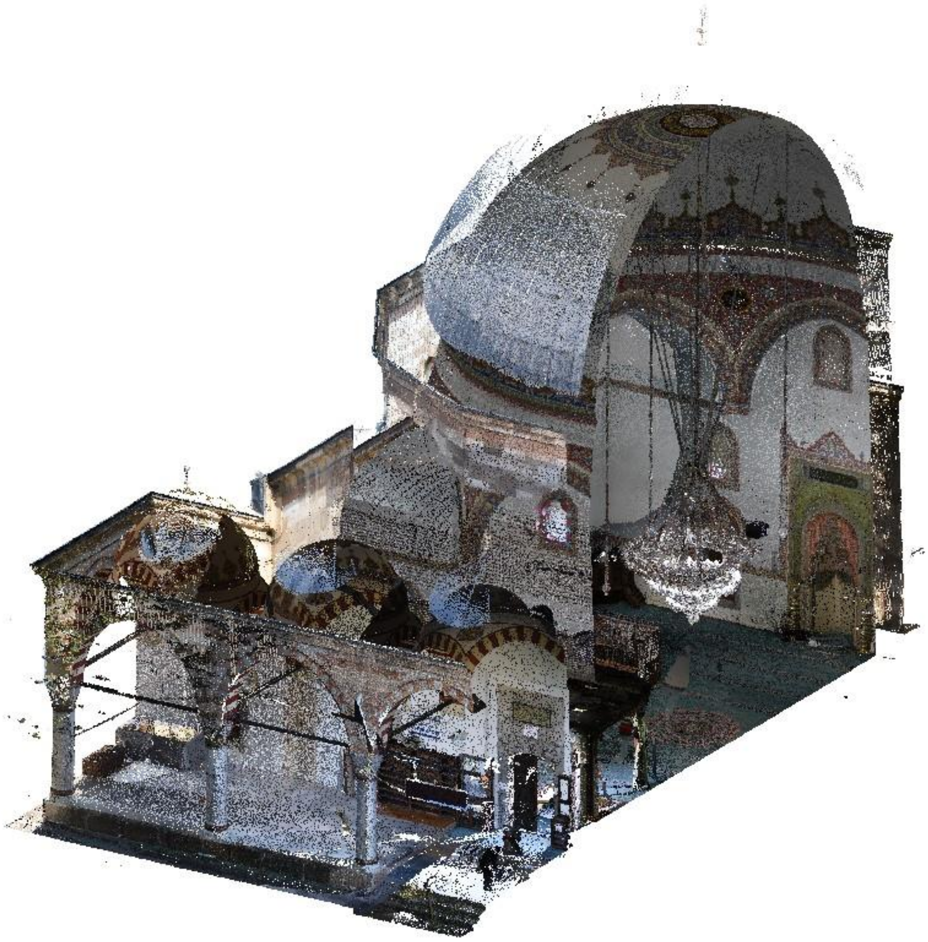

Figure 3. A cross section of point clouds generated with the terrestrial laser scanner.

4.2. Aerial photogrammetry

After the data obtained by the unmanned aerial vehicle (UAV) was subjected to photogrammetric processing, a point cloud consisting of a total of 21,023,345 points was produced in the final product. Due to the obstruction of the surrounding structures and tall trees, sufficient images could not be produced from the entrance section and southern facade of the building. In Figure 4, large gaps are seen in these sections where data was insufficient in the point cloud.

4.3. Terrestrial photogrammetry

In documentation with a camera, objects around the building also prevented the entire facade being photographed from every point and from the same distance to the building. This caused the overlap rates between consecutive frames to decrease and prevented the production of a comprehensive point cloud.

Inside the building, 80 frames of photos were processed with different depth filtering settings offered by the software in an attempt to produce a dense point cloud that could be used as a base. In this process, the data was first processed with the aggressive depth filter and a point cloud of 5,232,512 points was produced, but there was too much noise to allow the reading of the model. Subsequently, low-quality photos were deleted, and light and contrast adjustments were made on the remaining 63 images. In the newly created point cloud, the noise decreased, but it was evident that no points were produced on white surfaces. To produce points in these areas as well, the depth filter was lowered by one step and the photos were reprocessed with the moderate filter. It was concluded that the noise in the final product was caused by the inability to detect depth in the white surfaces (Figure 5).

Figure 4. The point clouds generated with the data obtained from UAV.

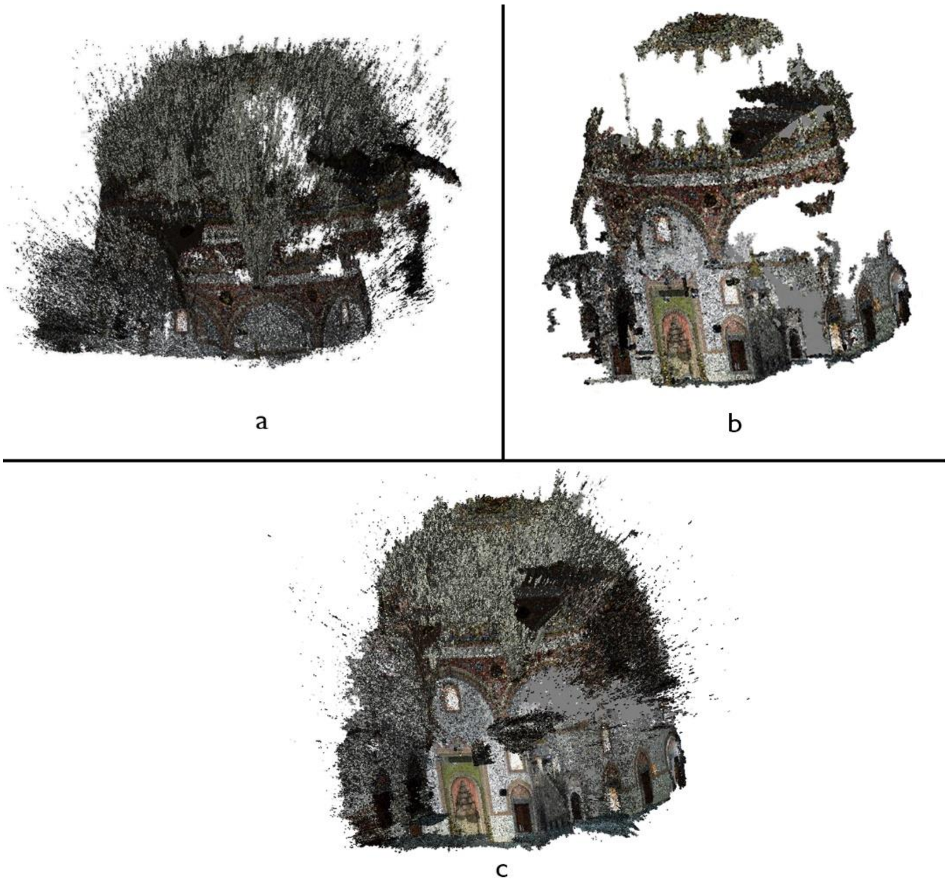

Figure 5. Point clouds are generated from camera images with different depth filter settings. a. processed with aggressive filtering using all photos, b. processed with aggressive filtering using best photos, c. processed with moderate filtering using best photos.

5. Results

5.1. Measurement sensitivity

For comparison, measurements of identical spaces were conducted both on the output obtained as well as conventional measurements. The diagonal measurements of the ground and the measurements of the west facade, which are common to all three methods, were taken as references in the comprehensive models produced. These measurements were compared with those made with a steel tape measure on site. When the results in Table 1 are examined, it is evident that the measurements made with non-invasive methods have sufficient accuracy for architectural drawing and modeling.

Table 1. Comparative measurements carried out on the western facade of the building.

	In-situ measurements (cm)	TLS (cm)	AP (cm)	TP (cm)
a. Left window jamb, short side	166	166,3	166	166
b. Left window jamb, long side	183	183,4	182,8	182,6
c. Right window jamb diagonal	212	212,8	212,5	211,9
d. Length of the Facade	1445	1444	1445	1444
e. Height of the facade	771	772,4	772,8	772,2
f. Diagonal measurements of the interior floor	2070	2074	-	-

5.2. Evaluation of outputs according to different analyses

As previously mentioned, drawings and models of architectural structures are needed for different reasons and the structure of outputs to be produced also varies as a result. Therefore, in addition to the drawing base for architectural surveying, solid models were also generated from the collected data for acoustic, structural, and daylight analyses; each requiring specific levels of detail.

It is important to note that no single method alone can generate a comprehensive model. While terrestrial laser scanning provided detailed data of the building's facades and interiors, it produced very few data points from the roof level. Conversely, the unmanned aerial vehicle generated detailed data from the roof level but was limited in capturing data from within the structure. The documentation work carried out with the camera also did not yield a cohesive result for model generation. Therefore, integrating measurement results obtained through different methods is required for comprehensive modeling. Integration was performed using "CloudCompare," an open-source software that effectively processes point clouds. With this software, common points in the existing point clouds were manually marked, allowing the alignment of two-point cloud data sets from the same area, resulting in a comprehensive dataset.

5.2.1. Drawing bases for architectural surveys

Architectural survey drawings are cross-sections and elevations that encompass all the details of a structure. Therefore, architectural survey drawings include plans of different levels as well as facade drawings [18]. Facade drawings require a greater level of information to visualize architectural details on surfaces. Orthophotos are photogrammetric outputs that provide both measurable and photographic information of these details. An orthophoto is a photograph or a set of photographs in which geometric and perspective distortions caused by differences in height, tilt, and curvature are corrected, resulting in a fixed scale image [19, 20]. It is possible to obtain orthophoto outputs with all the methods used in the study. However, data could not be generated from every point of the building using these methods. Therefore, only the west facade, which serves as a common surface for data generation, was used in orthophoto production.

Orthophoto production from terrestrial laser scanning data was performed using the orthophoto extension of the "Riscan Pro" software. For this process, the software requires models created by the triangulation method from positions that view the area where orthophotos will be produced. After these models are created, the 'undistortion' process, which corrects lens-induced distortions, is applied. Then, the orthophoto of the relevant area can be produced. Although the general details of the facade can be read, the low resolution due to the production of the orthophoto negatively affects its use as a base (Figure 6).

The steps for orthophoto production from data obtained with the camera and the UAV are identical. A 3D model was produced from the dense point clouds created in the "Agisoft Metashape" software. Then, the orthophoto of the west facade was produced using the software's orthomosaic tool. In both methods, the details of the structure can be easily read in the orthophotos. The UAV-sourced orthophoto has the advantage of including information regarding the upper structure, enabling the creation of a complete image which includes the drum area. Data could not be produced from the upper levels in the orthophoto sourced from the camera, as in the terrestrial laser scanner; but the visual quality of the produced orthophoto is higher than that of both methods (Figure 7).

When the generated orthophotos are evaluated as a base for architectural survey drawings, significant differences can be observed, especially in terms of material degradation details. In Figure 8, details of stone degradation, located near the left window on the second floor of the structure, are presented from the produced orthophotos. Although the degradation is discernible in all three methods, only the orthophoto produced with terrestrial photogrammetry provides a drawable level of detail. Many other deteriorations on the facade are also depicted in detail in the drawing based on this orthophoto.

With the floor plans, the only effective method capable of documenting both the interior and exterior of the structure was terrestrial laser scanning. They are therefore the only effective method for plan drawings which include wall thickness. However, the limited data generated for the roof structure hinders the production of the roof plan and sections. For this reason, integrated data was used. The generated point clouds were indexed in "Autodesk ReCap" software. This allows data containing a large number of points to be seamlessly used as a base in Autodesk Software Corporation's other software programs. The indexed point clouds were opened in "Autodesk AutoCAD" software, sections of desired thicknesses from different elevations were taken, and floor plans were created. Since it was possible to create vertical sections in the desired axis of the structure, elevation sections could also be quickly generated.

Figure 6. The orthophoto of the west facade produced from TLS data.

Figure 7. Orthophotos of the west façade. a. produced from UAV and b. produced from TF.

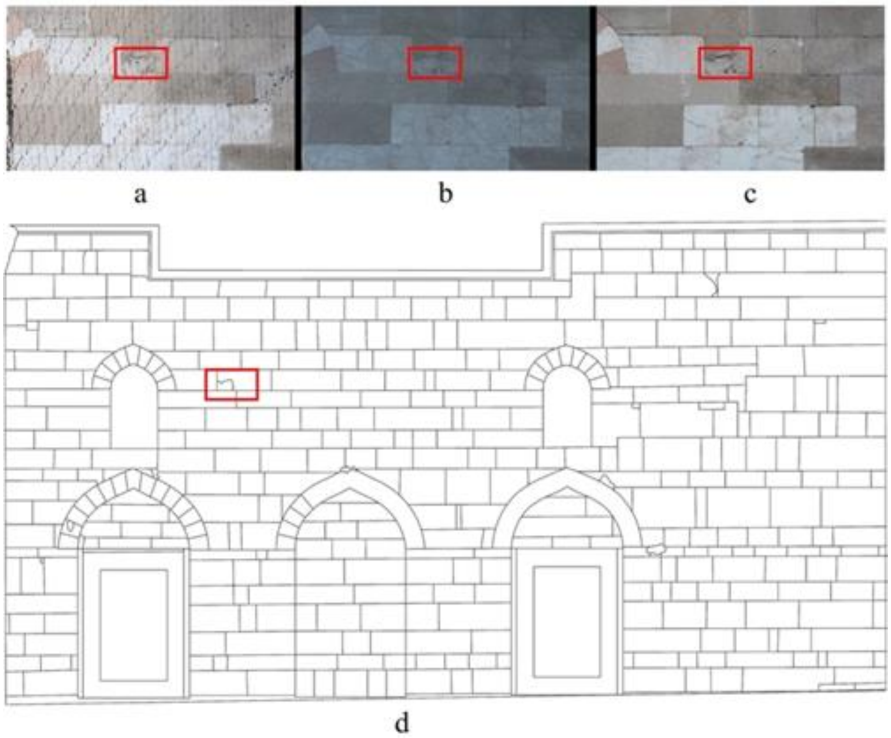

Figure 8. Details of the deterioration near the second-floor left window of the building. a. produced by laser scanning, b. produced by UAV, c produced by terrestrial photogrammetry method and d. survey drawing produced from terrestrial photogrammetric sourced orthophoto.

There are notable differences between plan drawings produced with the collected data and those used in publications. In publications related to the structure, the transition element to the dome is described as a squinch but drawn as semi domes in the plans. A squinch is a transitional element placed at the corners of a square-plan structure, transforming it into an octagonal shape and providing a more favorable surface for the dome to rest on [21]. A squinch consists of two arches at right angles to each other, which both ensure the load transfer of the system. In a semi-dome, which is essentially a continuous arch form, load transfer occurs through all surfaces. In other words, these two architectural elements function entirely differently from each other, and it is crucial for them to be accurately represented in architectural drawings. Slicing the comprehensive point cloud parallel to the ground at 10 cm intervals reveals how the squinch should be represented in plan drawings. Figure 9 shows sections taken from the point cloud following the plan used in publications and the plan drawn on top of this section.

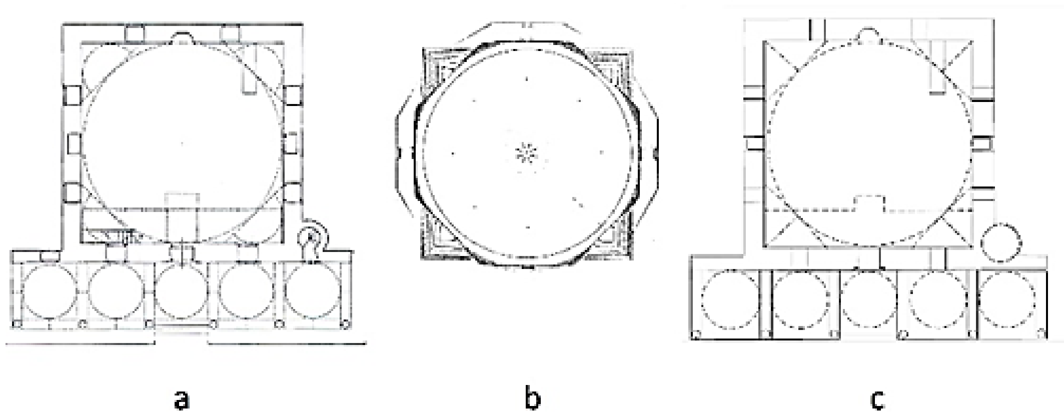

Figure 9. Plan drawings a. Drawing from publications [22], b. Horizontal sections from point cloud c. Plan drawing with the help of sections.

5.2.2. Solid model production for different analyses

To analyze structural elements in the computer environment, digital solid models are required. However, each analysis requires model production in different forms and details. Some require precise measurements of details such as wall thicknesses and arch spans, while others require simpler models. This directly influences the choice of measurement methods. Choosing the right measurement methods for accurate analyses directly impacts the time and cost of projects. The data produced from the measurement methods in this study were utilized to create models for acoustic, structural, and daylight analyses. Ultimately, the study aimed to determine the documentation methods required for model production at different levels.

Indoor daylight analyses were carried out with “Autodesk Revit” software. Since “Revit” is an Autodesk product, it can easily use the point clouds indexed in the “Recap” software as a base. In daylight analysis, it is crucial for window positions to be accurate in the models, for models to be sealed with no openings other than the windows, and for wall thicknesses to be included. Therefore, the models must be comprehensive and solid. With the indexed point cloud used as a base in the software, solid model generation was easily achieved, and daylight analysis was successfully conducted.

“Abaqus CAE” software was used as a reference for structural analyses. In these, all structural elements are drawn separately, and each element's materials and properties are be individually processed. With the help of “Revit,” even the most complex geometric structures, such as the main dome and squinches, were seamlessly created and transferred to “Abaqus CAE” software.

The “Odeon” software was used for the acoustic analysis. In such analyses, it is preferable to use models that are as simple as possible, composed of surfaces, with no gaps [23]. In this case, modeling only the inner surfaces of the structure in a shell-like form was sufficient. Terrestrial laser scanning provides these conditions per se. However, modeling the complex geometric structures of masonry architecture for the software poses some challenges. Particularly, models must not have gaps at points where circular elements like domes, half-domes, and squinches meet the angled body walls. Although solid models in different formats can be imported to “Odeon” software, a plug-in has been produced for “SketchUp.” For this reason, the model for acoustic analysis was produced in “SketchUp” software. The model was transferred to “Odeon” and tested using a validation tool, confirming the absence of any gaps.

6. Discussion and conclusions

The most prominent result in this study is the significant differences between conventional methods and non-invasive technology methods. With conventional methods, it is necessary to conduct field work during daylight hours, transfer measurement results to paper overnight, and make corrections on-site the next day [24]. This could mean spending at least two days in the field. Even with terrestrial laser scanning, which requires the longest time spent on site, both interior and exterior measurements of the structure were completed in a total of 1 hour and 40 minutes. For facade surveys, the photography process for photogrammetric production was completed in just a few minutes.

For conventional methods, three people usually need to be positioned on different parts of the field. While two people fix the measuring instrument, one person performs the readings [24]. In this study, all measurements were carried out by a single person.

The drawing error in the published floorplans of the structure emphasizes the importance of incorporating non-invasive technology methods into measurement processes. The fact that the dome transition element, a squinch, is represented as a semi-dome in plan drawings, have directly affected scientific studies to date. Documentation methods involved in the process should also be valued for preventing human errors.

In conclusion, no documentation method alone can collect enough data to produce a comprehensive model. Unless the terrestrial laser scanner is elevated from the ground, it cannot collect data from the outside the building or the superstructure. Although Kurşunlu Mosque is located on a quite hilly topography, there is no elevation allowing for this measurement. In addition, this mosque is relatively small in scale compared to other Ottoman structures of the period. Therefore, the terrestrial laser scanner alone is not sufficient for comprehensive documentation of monumental structures. With unmanned aerial vehicles, terrain conditions caused serious problems. Surrounding buildings and natural obstacles prevented the complete documentation of the mosque. Nevertheless, sensitive data production for modeling was provided from the outer wall and the superstructure. In data processing, a loss of precision was observed, especially in the corners of the building. With the terrestrial photogrammetric methods, it was not possible to evaluate the data obtained from inside the building. The large number of single-colored and prolonged surfaces within the building caused problems in creating the final outputs. To conclude, it is not quite possible to use a single method for a comprehensive documentation of a monumental architectural structure. Therefore, it is important to determine the methods to be used based on the characteristics of the structure and the type of desired final product before starting documentation studies.

Terrestrial laser scanning has come closest to producing comprehensive data. However, it was less successful in orthophoto production compared to other methods. The quality of the produced orthophoto is so low that it is not possible to draw on it. The inability to read details on the facade and the gaps in some places affected the quality and production speed of the result drawing. In the terrestrial laser scanner software, there is a long data processing time for orthophoto production. Considering the cost, it falls behind other methods, especially in orthophoto production.

Figure 10. Comparison of methods according to the outputs and relevant suggestions.

For data generation and processing, UAV and camera documentation have the same photogrammetric foundations [25-27]. Therefore, the same software and data processing methods have been used for both. However, the resulting orthophotos show differences. Among the three products, documentation conducted with a camera produced orthophotos are most suitable for reading facade details and for drawing on. However, some distortions have been observed in the orthophoto from documentation with a camera, especially towards the north side of the facade. The absence of distortions in the southern part indicates the necessity of taking photographs perpendicular to the surface. Large trees in the northern corner of the facade obstructed the capturing of images directly facing this area. Uncontrolled adjustment of the overlap ratio in the images and a limited number of photos resulted in empty spaces and distortions in the produced orthophoto. In the production of a facade survey base, terrestrial photogrammetry is the most efficient method in terms of time and cost. However, achieving sufficient accuracy and precision requires expertise in fieldwork.

The orthophoto produced from data obtained through UAV is clear and legible, allowing for easy drawing. The method's high overlap ratio in the photos and its ability to capture more data from the upper corners have reduced distortion. In the initial documentation, an accident led to the destruction of the UAV, but the chosen flight time ensured no significant damage was caused. This incident demonstrates that uncontrolled UAV use in large and densely populated cities carries critical risks.

Upon evaluating all these data, despite its disadvantages in terms of cost, speed, and the need for expertise, it is apparent that utilizing UAVs is the most effective method for facade survey due to the accuracy of the resulting output.

Methods that can be preferred depending on the nature of the analysis have been presented with strengths and weaknesses. In Figure 10, positive and negative aspects of each method are listed according to the desired output, and recommended methods are specified separately.

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Author contributions

Serhan Tuncer: Conceptualization, Methodology, Data Collection, Analysis, Investigation, Writing - Original Draft, Writing - Review & Editing
Uğur Avdan: Supervision, Validation, Writing - Review & Editing

Conflicts of interest

The authors declare no conflicts of interest.

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