

Application Of Multi-Source Photogrammetric Data For Fast Building Inventory

Anna Fryśkowska-Skibniewska, Patryk Wróblewski, Klaudia Pasternak, Julia Gotowiec

Faculty of Civil Engineering and Geodesy, Military University of Technology, gen. Sylwestra Kaliskiego 2, 00-908 Warsaw, Poland

anna.fryskowska@wat.edu.pl, patryk.wroblewski@wat.edu.pl, klaudia.pasternak@wat.edu.pl, gotowiec.julia@gmail.com

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Abstract

The rapid expansion of urban areas and the continuous demand for their monitoring make remote sensing data a highly valuable tool for collecting large volumes of geospatial information in a relatively short time and with high repeatability. The main objective of this paper is to examine the potential offered by different types of geospatial data, as well as the relationships based on their scope, in comparison with measured reference data.

Architectural inventory tasks are useful not only for engineering projects but also for broader applications, such as environmental impact assessments, spatial planning, and related fields. This article introduces a rapid and cost-effective mixed-mode data collection framework for building inventory development, integrating terrestrial laser scanning, UAV imagery, and traditional ground measurements.

The paper will discuss the latest measurement technologies and their practical applications in building surveying, illustrated with a selected case study. The criteria for selecting appropriate measurement methods will also be analyzed, depending on the investor's requirements and the intended use of the documentation.

This paper presents a set of techniques for updating the geometric information of buildings using laser scanning and imagery. It begins with an introduction to the fundamental concepts, terminology, and principles of 3D information. Subsequently, various measurement techniques are described, along with a discussion of potential sources of error and data incompleteness. The extracted geometric values are validated against independent survey data.

1. Introduction

The inventory provides all the necessary information for the planning of building projects and installation measures as well as the structure of facility management systems (FM), documentation and information systems (GIS/BIM), and we perform it with all the necessary surveying and field work. In the past two decades, numerous initiatives have been undertaken to collect building inventory data for exposure modeling (Shah et al., 2024). Each approach involves a particular balance between the resources invested and the level of data completeness or reliability achieved. In papers such (Jo and Kim, 2017, Calisi, D. et al., 2023, Haala and Alshawabkeh, 2006) combination of different methods for heritage documentation is presented.

This section outlines the most commonly applied strategies.

The completeness and resolution (in case of BIM - level of detail) of a building inventory depend on its intended application—such as policy development, emergency response planning, heritage and architectural use, or recovery planning—as well as on the size of the study area, time constraints (Dell'Acqua et al., 2013). There are few main attributes generally required to support building inventory development for practical use cases: geographic location (longitude and latitude), height or number of stories, footprint area, total square footage, structural class (construction type), usage or occupancy of buildings, age or year of construction, plan and elevation irregularities (re-entrant corners, setbacks and etc.), cladding type, roof shape, roof type and etc. Several of these attributes can directly be extracted from remotely sensed data -such as the data collected by aerial photography or satellite imagery. Height, footprint and other geometric features of buildings are among this group of attributes: location, geometric dimensions (height), roof shape, building type, materials, building use etc. These attributes are derived from widely recognized taxonomies, including the Global Earthquake Model GED4ALL building taxonomy (Silva

et al., 2022), RiskScape (GNS, 2010), the European Macroseismic Scale 1998 (EMS-98; Grünthal, 1998), HAZUS (FEMA, 2003), and the Prompt Assessment of Global Earthquakes for Response (PAGER) structural taxonomy (Jaiswal et al., 2010) (Opabola et al., 2022).

To obtain complete and highly accurate data, increasingly advanced tools are being used. (Błaszczak-Bak, W. et al., 2024., Pirotti, F. et al., 2022, Ruiz, P. R. S. et al., 2021). A safe and reliable technology is remote sensing, which enables fully remote and contactless acquisition of geospatial data about objects. (Montoya, 2003) suggested that a combination of remote sensing, global positioning systems (GPS), digital video using manned vehicles, and geographic information systems (GIS) data can be used for building inventory data collection purposes. (Nex and Remondino, 2014) show the UAV data aspect in such purposes, the same (Gerke, M et al., 2016, Jo and Kim, 2017) or (Błaszczak-Bak et al., 2024).

The scope of the study covers the analysis of methods for acquiring and integrating geospatial data in order to create reliable technical documentation of buildings.

Modern surveying technologies enable the use of various data sources, such as geodetic measurements, laser scanning, aerial and terrestrial photogrammetry, and satellite imagery. The selection of an appropriate data acquisition method is crucial for the accuracy of the resulting documentation, which in turn affects its quality and usefulness.

Depending on the purpose of the survey — such as building renovation, change of function, implementation of Building Information Modeling (BIM), heritage preservation, or energy efficiency analysis — the required level of detail in the documentation may vary significantly. For historical buildings, maintaining high precision in representing architectural details is

essential, while for industrial facilities, functional and structural aspects are often of primary importance.

The paper discusses the latest measurement technologies and their practical applications in building surveying. It also analyzes the criteria for selecting appropriate measurement methods according to the investor's needs and the intended purpose of the documentation. The proposed framework has been developed to enable accessible, rapid, cost-effective, and comprehensive data collection on structural and non-structural attributes of small and large buildings.

2. Study Area and Data

2.1 Study Area Description

The building complex selected for analysis consists of two structures connected by a garage space (Figure 1).

On the left side, there is a two-storey residential building constructed using traditional masonry techniques. The structure features a multi-pitched roof covered with sheet metal. Several chimneys and smaller roof windows are visible on the rooftop.

On the right side, there is a utility building with an integrated garage, characterized by a simpler form and a larger roof surface. Its single-pitched metal roof is equipped with photovoltaic panels. The light-coloured façade and simple window openings indicate a functional or storage use of the building.

Between these two structures, a series of garages connects the buildings. The garages are of simple geometric form with light façades and single-pitched roofs, also covered with sheet metal. (Figure 1).



Figure 1. Building chosen for analysis.

In order to prepare the technical documentation of the building, geospatial data acquired from multiple sources were utilized, including geodetic surveying, photogrammetric measurements, and laser scanning. The combination of these complementary measurement techniques allows for the acquisition of high-precision data, which serve as the foundation for reliable and detailed building documentation.

1. Terrestrial Laser Scanning (TLS): The data were acquired on January 22, 2024. A point cloud was obtained using the Leica RTC360 laser scanner. The instrument provides a measurement accuracy of approximately 1 mm at distances up to 10 meters, while at greater distances the accuracy remains within a few millimetres. The scanner operates based on Time-of-Flight (ToF) technology, using laser pulses to measure distances and generate a point cloud. For the building survey, 42 scanning stations were established (Figure 2). The point clouds from individual stations were registered in Leica Cyclone REGISTER 360 PLUS software with an alignment accuracy of 2 mm. The error on the

reference points was also 2 mm. The laser scanning data acquired with the Leica RTC360 were processed and integrated in Leica Cyclone software. The accuracy of the final point cloud was determined in AutoCAD after generating a cross-section through the dataset.

The cross-section was created at a height of 1.50 meters above ground level, with a section thickness of 0.03 meters. Within the interior walls of the garage part of the building, the "thickness" of the point cloud was measured at approximately 0.005 meters, while in the exterior parts of the building it ranged from 0.004 to 0.008 meters.

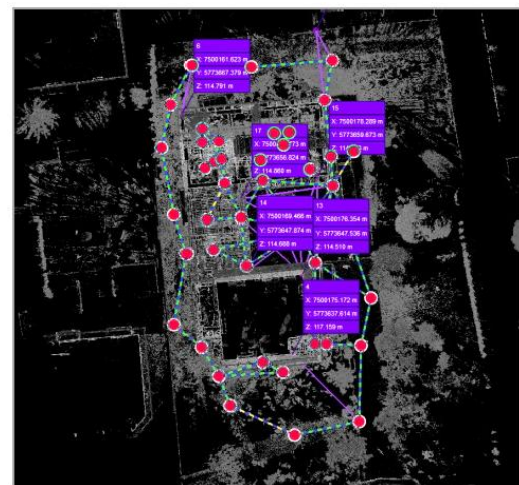


Figure 2. Scanning stations and point clouds - TLS.

2. Low altitude UAV: For the purpose of documentation, 24 oblique and 22 nadir (orthogonal) images were acquired using a DJI Mavic 3 Pro UAV. This combination of images allows the generation of precise products, such as a Digital Surface Model (DSM), an orthophoto, and a point cloud. The flight altitude was 60 meters. The data were processed in Agisoft Metashape, producing both the point cloud and the orthophotomap.



Figure 3. Low altitude point cloud from images.

3. Close-range imagery: During the on-site survey, photographic documentation was also performed, which is highly important and useful, especially when processing data acquired with a laser scanner. For this purpose, a Ricoh Theta S camera was used. This is a compact 360-degree camera capable of capturing spherical images and videos. It is equipped with two fisheye lenses, which together create a complete view of the surroundings in a single capture. The images have a resolution of 12 megapixels.

4. Total station and GNSS reference data: The control points used for accuracy assessment were measured

with a Leica TS09 total station, which provides a measurement accuracy of 0.1 mm.

The reference points were measured using a Leica Viva GS14 GPS receiver. According to the manufacturer, the declared accuracy in RTK mode is $\pm 8 \text{ mm} + 1 \text{ ppm}$ in the horizontal component and $\pm 15 \text{ mm} + 1 \text{ ppm}$ in the vertical component, ensuring very high precision even at distances of several kilometers from the reference station.

3. Methodology

A multi-source data collection and further integration necessary to form complete spatial building model. Based on existing research applying remote sensing technology and combining a bottom-up method to fast analyse building attributes, the methodology includes three basic steps: 1) proper data collection; 2) accuracy and completeness analysis; 3) multi-source data integration and 4) quality check. (figure 4).

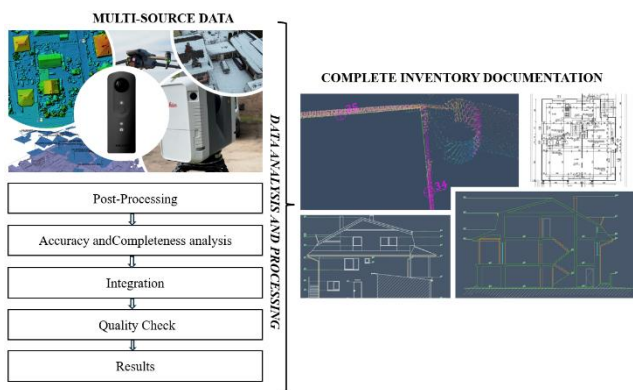


Figure 4. Low altitude point cloud from images

This study focuses on evaluating the suitability of measurement methods used in architectural surveying, including both geodetic and remote sensing techniques, with emphasis on their accuracy, applications, and limitations.

Initially, the paper presents key contemporary technologies and methodologies for acquiring geospatial data of building structures, covering traditional surveying approaches, such as total station measurements, as well as modern solutions, including laser scanning, aerial photogrammetry, and terrestrial photogrammetry. The technical parameters of each method, their measurement precision, and their applicability in building inventory documentation are discussed in detail.

In addition, an analysis of the utilization of different data types within the surveying workflow is performed, enabling an assessment of their efficiency and identification of optimal strategies for integrating multiple data sources to generate the most comprehensive and accurate results.

3.1 Data Post-processing and Integration for Preparation of the complete documentation

The raw data underwent a processing workflow to obtain a georeferentially accurate and noise-free point clouds. The UAV flight trajectory was determined in Post-Processing Kinematic (PPK) mode using Agisoft Metashape software and observation data from national reference stations network. The GNSS observations also have been adjusted. Terrestrial Laser Scanning Point clouds from different stations were transformed into one

coordinate system. All accuracy investigations were discussed in section Accuracy analysis.

In order to integrate data from different measurement methods, all datasets must be registered into a common reference system. To achieve this, a transformation based on control points was performed. These control points were measured using a Leica Viva GS14 GNSS receiver.

To ensure proper georeferencing and the required accuracy of the processing, ground control points — markers with known spatial coordinates — were distributed throughout the survey area (figure 5). These targets were captured both in the imagery and measured using geodetic methods, such as GNSS or total station surveys.

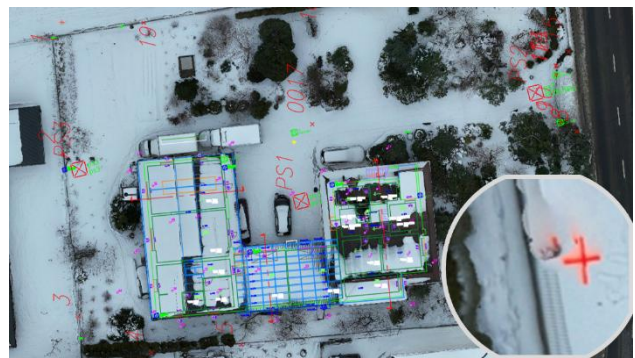


Figure 5. Ground control points network.

Based on measurements acquired using a terrestrial laser scanner, which generates a point cloud, it is possible to develop detailed technical documentation that also includes elements of the building's internal installations. This documentation allows for highly accurate representation of the layout and condition of visible installation components, as well as endpoints such as lighting fixtures, radiators, light switches, or electrical outlets. The high resolution of the data enables precise modeling of these details, which is essential for further analysis, renovation, or design work.

When preparing floor plans, an important aspect is creating a room schedule specifying each room's function and area. Room areas are calculated by generating closed polylines at floor level, taking into account raised features below 0.30 meters. All elements on the floor, such as walls exceeding 0.30 meters in height, columns, or permanent structures, are subtracted from the area. Doorway areas are also excluded from the calculated floor surface. To prepare a plan view of the roof, the point cloud—acquired, for example, from low-altitude imagery—serves as a primary source. This dataset is complemented by an orthophotomap, which, thanks to proper georeferencing and geometric alignment, provides an accurate top-down representation of the roof surface with true dimensions and proportions. Both sources serve as mutually complementary tools for spatial analysis. The point cloud (Figure 5) enables three-dimensional modeling of the roof planes, allowing for geometric analysis, including the identification of slopes, breaks, ridges, edges, and technical elements (e.g., vents, skylights, air-conditioning units). The orthophotomap, in turn, allows for rapid recognition of the spatial arrangement of these elements in plan view and supports the interpretation of point cloud data, particularly with regard to surface textures and color information (Figure 6). The orthophotomap also facilitates precise measurements.

In the process of generating the roof plan, elevation points derived from the point cloud play a crucial role. These indicate the height of specific points relative to the adopted reference level, or the so-called zero point of the project. This allows for accurate determination of height differences across roof planes and precise representation of their geometry in the technical documentation. The high quality of both the point cloud and the orthophotomap directly affects the reliability and accuracy of the final product. Proper processing and interpretation of these datasets allow for the creation of a detailed roof plan, which can serve as a basis for further design, renovation, or conservation analyses.

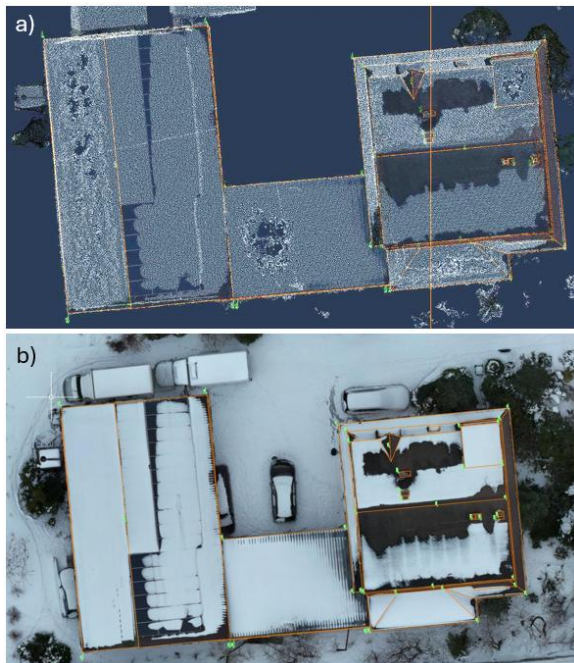


Figure 6. Roof plan derived from a) 3D low altitude point clouds from UAV images, b) UAV orthophoto.

After preparing all building plans, including the roof, it is possible to generate a building cross-section. For this task, it is essential that all plans include floor levels—so-called elevation points—as well as the heights of rooms and all door and window openings. The cross-section should depict the main structural elements of the building, such as floors, load-bearing walls, the roof, and any level differences between stories. Additionally, significant finishing elements should be indicated, and cross-sections through windows and doors should be included if they intersect the cutting plane. In figure 7 there is example of such products.

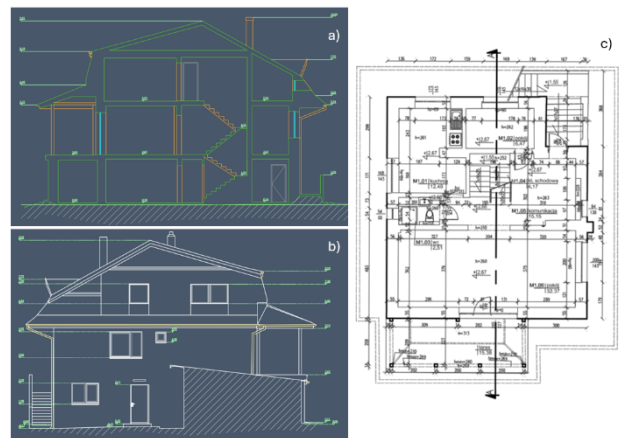


Figure 7. Examples of plans: a) Cross-section through the building, b) building elevation, c) documentation.

Window and door openings that lie along or are visible in the cutting plane should be placed on appropriately assigned layers, similar to those used in the building plans. A correctly executed cross-section allows for the assessment of the building's proportions, structural analysis, and a better understanding of its spatial functions. It constitutes an essential part of architectural and construction documentation, used both during the design and construction phases, as well as in later renovations or technical condition assessments.

4. Results and Discussion

4.1 Accuracy Analysis

The accuracy of technical documentation generated from laser scanner data depends on multiple factors. A primary factor is the point cloud density, which is influenced by the scanner settings and the density of scanning positions. Increasing the number of scanning stations contributes to better overlap between scans and, consequently, higher point cloud accuracy. The scanned surface also plays a significant role. Highly reflective surfaces, such as tiles, mirrors, decorative elements, or large windows, generate substantial noise, which can affect the point cloud precision. Also other researchers like in (Peterson et al., 2019 or Remondino et al., 2021, Rönholm et al., 2019, Zhang et al., 2020), emphasize the accuracy of photogrammetric data, including TLS and UAV images.

To verify the accuracy of the point cloud and the correctness of scan alignment, cross-sections are typically generated in software such as ReCap or AutoCAD. The thickness of the point cloud is then assessed. For wall surfaces in cross-section, a thickness of approximately 3–4 cm indicates a sufficiently accurate point cloud, suitable for building inventory purposes, renovation planning, property tax assessment, or as-built documentation.

Cross-sections through the point cloud also reveal any misalignments or errors in the registration process. In such areas, the point cloud may appear doubled or visibly shifted in one direction.

An additional tool for improving element interpretation is the creation of RGB-colored point clouds. Color information facilitates the recognition of elements within the cloud. For example, small lighting fixtures are difficult to discern in a monochromatic point cloud, but when illuminated, they appear as brighter spots in a colorized point cloud. Generating an RGB point cloud is possible with scanners capable of capturing

images. Such colorized point clouds are particularly useful for documenting damage, defects, or missing sections of walls.

The numerical assessment of post-processed data accuracy focuses on evaluating the registration quality of individual point clouds or photogrammetric blocks within the overall dataset. The analysis of reports from Leica Cyclone REGISTER and Agisoft Metashape focuses on evaluating the quality and accuracy of 3D data obtained from laser scanning and photogrammetry, respectively. In the case of Leica Cyclone REGISTER, the primary focus is on the quality of the registration of point clouds acquired from different scanning stations. The report provides information on registration errors (RMS), which indicate how well individual scans were aligned.

Reports from Agisoft Metashape concentrate on assessing the quality of images and the alignment process. This includes evaluating the number and quality of tie points, the accuracy of camera position reconstruction, and RMS errors relative to control points (GCPs). TLS point cloud data comparison with ground truth was carried out through points pinpointing and extracted for measurements from the point cloud. Additionally, the reports provide information on the quality and resolution of the generated point cloud, 3D model, and orthophotomap. In both cases, the aim of report analysis is to assess the reliability, precision, and usability of spatial data for further applications.

- 1. Analysis of Reports for TLS:** Most scan registrations achieved excellent results, with mean alignment errors ranging from 0.001 m to 0.006 m, confirming the high accuracy of the scanner and the effectiveness of the Cyclone registration algorithms. The majority of errors did not exceed 0.003 m, which is considered very good for 3D geodetic measurements. Many links in the dataset exhibited high scan coverage, with values above 60% indicating good visibility of common geometric features between scanning stations. For example, some links achieved coverage between 65–79% while maintaining low alignment errors, demonstrating stable and accurate integration of spatial data.

Particular attention should be given to links with exceptionally low errors around 0.001 m, which represent the most precise alignments in the dataset. Conversely, a few links exhibited low coverage (below 30%) and higher alignment errors of 0.005–0.006 m, potentially indicating visibility issues, insufficient common features, or challenging field conditions. These connections may reduce the overall quality of the registration and should be carefully reviewed; they may require correction or reprocessing.

It should be noted that errors of 0.005–0.006 m, while higher relative to other connections, are still within acceptable limits for many engineering and construction applications, though caution is advised when developing highly precise models. Some links involve stations with coverage below 40%, which may indicate limited common areas or changes in environmental conditions between scans. While RMS errors in the range of 0.002–0.004 m are not disqualifying, their lower quality should be considered during the interpretation of spatial results.

- 2. Analysis of Reports for UAV point clouds:** In the case of point cloud generated from low-altitude UAV imagery, 22 nadir (orthogonal) images were used. The flight altitudes were stable – about 162 m. Geolocation errors of the images were low, ranging from 0.006 m

to 0.037 m, which is an excellent result and demonstrates the high precision of both the equipment and the reconstruction algorithms in the software. The smallest error was 0.006 m, and the largest 0.037 m. Most errors fell within 0.011–0.023 m, indicating good consistency and data quality across the dataset. The spatial distribution of images also confirmed proper coverage of the survey area without significant deviations.

For oblique images, a total of 24 images were included. Compared to the orthogonal images, greater variability in flight altitude was observed, ranging from 160.7 m to 162.9 m, which is typical for oblique imagery, as these images are captured at varying angles and altitudes to capture vertical structures. Positional errors of the oblique images ranged from 0.005 m to 0.038 m, with 0.038 m being a single instance of the highest deviation. Most errors were between 0.007–0.023 m, confirming high precision despite more complex drone trajectories and greater spatial variation of the images. A slight decrease in altitude is also visible in some regions, likely due to intentionally lower flight levels to better capture details in this part of the site.

4.2 Completeness analysis of archived products

As part of the building's spatial data processing, two point clouds representing the roof were acquired from different sources, differing in terms of information content, density, and data quality. These datasets were analyzed in terms of their suitability for generating roof documentation and identifying roof geometry and structural elements.

The first point cloud was obtained using a terrestrial laser scanner (TLS). In the grayscale visualizations shown in Figures 8a and 8b, mainly the roof edges, outline elements, and lower structural parts, including the eaves, are visible.

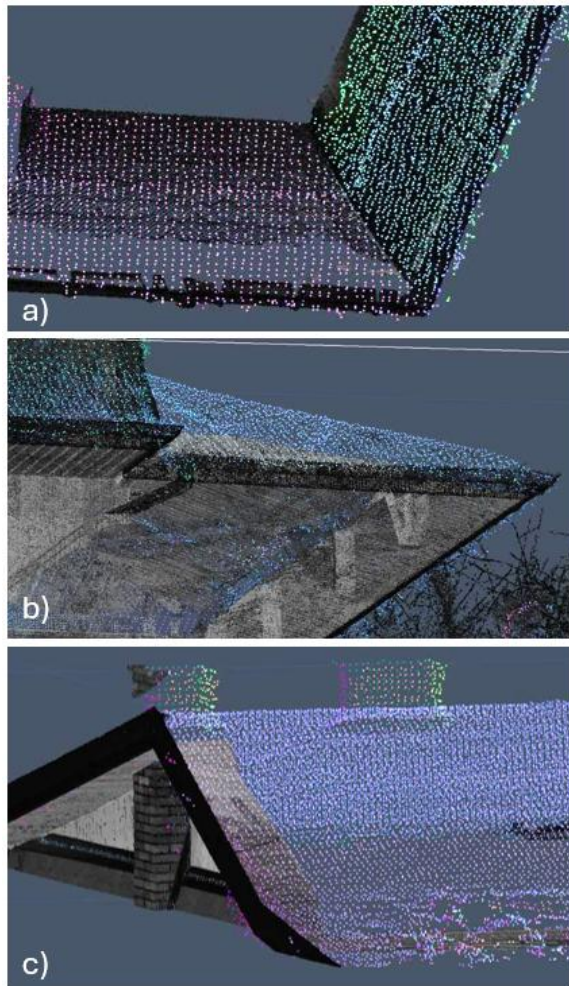


Figure 8. Point clouds from TLS – gray scale and UAG image-based - RGB a) roof corner b) roof eave, c) roof ridge.

This limitation is due to scanning being performed from the ground level only, without access to the roof itself, restricting the capture of upper roof sections. As a result, this point cloud contains valuable information about the position and course of the lower edges of the roof planes, eave geometry, and spatial relationships between the roof and the building walls. However, due to the lack of direct optical access to the roof surfaces, the data are incomplete and do not allow for a full analysis of roof coverage, slopes, or potential technical details (e.g., chimneys, skylights, or installations).

The second point cloud was generated through photogrammetric processing of low-altitude imagery, captured from approximately 50 meters using an unmanned aerial vehicle (UAV). In the color visualization shown in Figure 8c, all roof planes, covering, details, and technical elements are visible. This dataset provides comprehensive geometric information for the roof surface, enabling analysis of its shape, inclination, water drainage directions, and arrangement of structural elements. Nevertheless, a significant limitation of this point cloud is its relatively low density. It contains far fewer points compared to the laser scan, resulting in lower precision in representing details and limited accuracy in geometric reconstruction, particularly in areas with uniform textures or shadows. A complementary source of information is the orthophotomap, which effectively represents the roof planes and aids in interpreting structural and technical elements.

In the context of using these datasets for roof documentation, both point clouds have complementary significance. The TLS point cloud, although lacking surface information for the roof planes, provides high precision regarding the roof outline and its spatial relationship with the building mass. Conversely, the photogrammetric point cloud obtained from low-altitude imagery enables a complete view of the roof. Roof coverage measured using this method provides more reliable and comprehensive data.

Points in the UAV-derived cloud are distributed evenly, with distances between points ranging from 0.05 to 0.10 meters, resulting in a density of approximately 200 points/m². For a roof plane measuring 12 × 16 meters, this yields an average of 38,400 points, allowing these data to be effectively used for roof documentation.

Using both data sources together enables the creation of a more complete and reliable roof model: TLS provides precise base data for edge geometry and eave levels, while UAV imagery fills in missing information about roof surfaces and covering. An optimal solution would include additional scans from the roof level or higher observation points (e.g., booms or LiDAR-equipped drones), which would mitigate visibility gaps and improve the accuracy of the final documentation.

Data acquired with a low-altitude UAV, while useful for documenting roofs and upper building elements, prove insufficient for comprehensive inventory of the entire exterior. The main limitation is the lack of information in critical zones, especially under the roof eaves and areas outside the camera's field of view during orthogonal or low-angle flights. In the view presented in Figures 3 and 6, gaps in data for the upper wall sections are evident, resulting from limited viewing angles and architectural features (such as overhanging roofs). Due to the flight altitude of approximately 50 meters and the applied image capture angles, the camera was unable to capture details near vertical wall planes.

Point spacing in the photogrammetric cloud ranges from 0.07 to 0.18 meters, but gaps and areas with sparser coverage exist, where distances between points reach approximately 0.42 meters. Such captures, while effective for roof documentation, do not provide full visibility of facades, making them insufficient for complete inventory purposes. To obtain full and precise data on building facades, it is necessary to perform flights at steeper angles or dedicated vertical flights specifically for facade documentation and generation of products such as orthophotomaps or point clouds. Ground-based scanners are also highly recommended for this purpose.

5. Discussion

The study demonstrates that more detailed information about building walls can be obtained using a terrestrial laser scanner (TLS). Since these data are captured from ground level, around the building, and at short distances, it is possible to acquire highly detailed and precise information about the geometry of the facades. The laser scanner allows the registration of millions of points in a very short time, resulting in a dense and homogeneous point cloud that accurately represents all visible wall elements – including planes and architectural details such as balconies and window openings.

A critical aspect of terrestrial laser scanning is the careful planning of scan positions, i.e., the locations from which scans

are performed. Because TLS measures distances with laser light and requires direct visibility of surfaces, adequate coverage of the entire facade must be ensured. This entails performing a sufficient number of scans around the building so that every wall segment is visible from at least two different scanner positions. This approach prevents so-called measurement shadows, i.e., areas not visible from a single scan position (e.g., window recesses, arcades, or obstructions caused by vegetation or small architectural elements).

Point spacing in the TLS-derived cloud ranges from 0.005 to 0.050 m, resulting in an average density of approximately 4,000 points/m². For a wall measuring 6 × 10 meters, this yields approximately 240,000 points, providing highly precise data suitable for documentation. However, TLS data do not provide complete information about the building's roof, which complicates analysis and comparison with photogrammetric data.

An orthophotomap generated from low-altitude UAV imagery provides higher resolution (1.5 cm/pixel), due to the lower flight altitude (~50 m) and inclusion of oblique images at a 35° angle, which enhances the quality of the collected information. Image coverage for the flight was approximately 60%, and the combination of nadir and oblique images allowed the generation of high-quality products. In contrast, orthophotomaps downloaded from geoportals typically have lower resolution (25 cm/pixel) and are based on imagery captured from altitudes of approximately 2,000–3,000 meters.

The building footprint was also measured using a total station for verification purposes. This measurement enabled independent assessment of the accuracy of the TLS-derived data. Tachymetry provides very precise point data in selected locations, particularly at corners and characteristic points along the building outline. Due to its high accuracy (0.002–0.005 m), tachymetry is well-suited for validating and calibrating data from other sources. In Figure 9, a set of selected total station-measured points is presented. These points were chosen to represent various sides of the building, allowing evaluation of scanner data accuracy along the entire perimeter. In the visualization, green lines and pink points correspond to total station measurements, facilitating their comparison with the TLS-derived point cloud.

Comparison shows very good agreement between total station measurements and the point cloud data. A cross-section of the point cloud, created at 1.5 meters above ground level with a thickness of 0.3 meters, allowed precise comparison between the two methods. The analysis of deviations showed that differences between total station positions and corresponding points in the TLS cloud do not exceed 0.01 m. Such a low error confirms the high accuracy of TLS data.

In practice, this means that terrestrial laser scanning can successfully replace traditional total station surveys, particularly when rapid data acquisition for the entire building is required. TLS offers the advantage of quickly collecting large volumes of spatial information while maintaining sufficient precision for inventory, design, or documentation purposes. Furthermore, the laser scanner captures not only outline points but also entire facade surfaces and architectural details, significantly expanding the range of data use in further processing.

The Ricoh Theta S camera was used for additional inventory documentation. This was helpful in interpreting details and for comprehensive visualization. No 3D model was created based on this data.

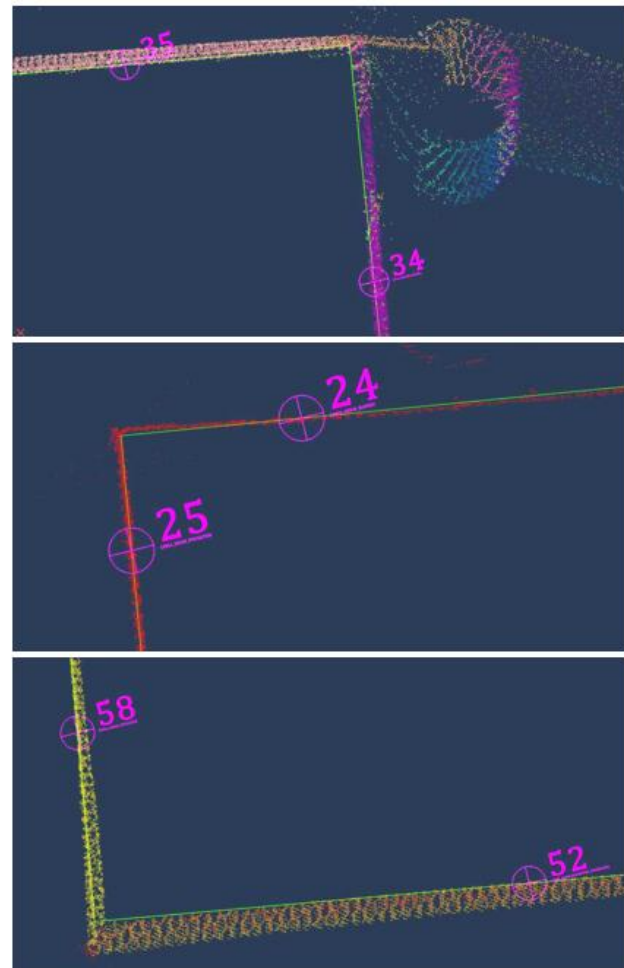


Figure 9. Examples of comparison between plan accuracy obtained from total station measurements (green line) and RGB point cloud data.

6. Conclusions

Many data types may be used to gather an inventory of buildings based on remote sensing. Critical risk assessment building elements such as the year of construction, building height, and building size may be determined. Contemporary measurement techniques offer a wide range of possibilities for architectural surveys, heritage documentation, and object modeling in BIM environments. The choice of an appropriate method, however, depends on several factors, including the required accuracy, project duration, site conditions, accessibility of the building, and the scope of the survey. Each method – total station, laser scanning, UAV photogrammetry, and terrestrial photogrammetry – has its own advantages and limitations, which must be carefully considered before undertaking measurement tasks. In summary, there is no single universal method that is ideal for every type of survey. In practice, a hybrid approach is most commonly used, combining tachymetry for precise measurements, laser scanning for comprehensive building geometry capture, and photogrammetry (both UAV and terrestrial) to supplement data and generate orthophotomaps. Only such a combination of methods enables the creation of a comprehensive, accurate, and reliable documentation of a building's exterior.

This study's primary goals were to analyse the applicability, accuracy, and limitations of contemporary measurement techniques for architectural surveys and building documentation.

The research focuses on the integration of multiple spatial data sources, including tachymetric measurements, terrestrial laser scanning (TLS), UAV-based photogrammetry, and terrestrial photogrammetry, to create a comprehensive, precise, and reliable building inventory. The study aims to evaluate how these methods complement each other in capturing both the external geometry of buildings, including roofs and facades, as well as fine architectural details and interior features where accessible. Furthermore, the work seeks to assess the accuracy and completeness of data products, such as point clouds, orthophotomaps, and building plans, and to demonstrate the advantages of a hybrid approach combining traditional surveying with modern remote sensing techniques for practical applications, including BIM modeling, heritage documentation, and structural analysis.

Although the study addressed multiple objectives, the main conclusion is that photogrammetric data provide reliable information for precise building inventory extraction. The results demonstrate that only the combined datasets can support the extraction of various types of building information efficiently. This capability is particularly valuable in applications where time is limited and rapid acquisition of building inventory data is crucial for subsequent analyses, including structural assessments and seismic evaluations.

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